THE EFFECT OF A RHYTHMIC MOVEMENT INTERVENTION ON SELECTED BIO-MOTOR SKILLS OF WESTERN PROVINCE RUGBY ACADEMY PLAYERS

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Thesis presented in partial fulfilment of the requirements for the degree of Master of Science (Sport Science) in the Faculty of Medicine and Health Sciences at Stellenbosch University

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March 2020

DECLARATION

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own original work, that I have read and understand the Stellenbosch University Policy on Plagiarism and the definitions of plagiarism and self-plagiarism contained in the Policy [Plagiarism: The use of the ideas or material of others without acknowledgement, or the re-use of one's own previously evaluated or published material without acknowledgement or indication thereof (self-plagiarism or text-recycling)]. I also understand that direct translations are plagiarism. Accordingly, all quotations and contributions from any source whatsoever (including the internet) have been cited fully. I understand that the reproduction of text without quotation marks (even when the source is cited) is plagiarism.

The co-authors of the one article that form part of this thesis, Dr Eileen Africa (supervisor) and Dr Wilbur Kraak (co-supervisor), hereby give permission for the candidate, Ms Jocelyn Solomons, to include one article as part of a Master's thesis. The contribution (advice and support) of the co-authors was kept within reasonable limits, thereby enabling the candidate to submit this thesis for examination purposes. This thesis, therefore, serves as fulfilment of the requirements for the degree Master of Science in Sport Science at Stellenbosch University.

March 2020

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DEDICATION

This thesis is firstly dedicated to two people who I would have loved to have around to witness my journey. To my dad and my coach, I am so blessed to have had the two of you in my life. The biggest supporters I could pray for. I was blessed beyond measure and still consider myself lucky to have the two of you with me in spirit.

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SUMMARY

The inclusion of other non-traditional approaches to training has become more popular within rugby conditioning. Rhythmic movement, also referred to as "dance", involves the execution of different motor skills, the integration and sequencing of actions between limbs, timing and spatial precision. It requires performing movement tasks to auditory rhythmic patterns and as a multifaceted activity, it depends on a large number of elements with direct and indirect effects on the physiology and physical attributes of a player. In terms of rugby conditioning the common belief dictates that fitness or conditioning elements should be developed through focused, isolated training blocks. The technical, tactical and physical conditioning for rugby has primarily consisted of traditional, rugby-based approaches to training as indicated by the majority of current research. However, in order for rugby coaches and specialist coaches to gain a competitive edge over opposing teams, they need to find new innovative ways to adapt their training methods and programmes in order to accommodate the changes to the profile of the game.

The primary aim was to investigate the effect of a rhythmic movement intervention on selected bio-motor skills of rugby players in the Western Province Rugby Union Academy. The first objective of the study was to investigate the effect of a 16-week rhythmic movement intervention on flexibility, dynamic balance, agility, power and local muscular endurance of these rugby players. The second objective was to compare selected bio-motor skills of backs and forwards after participating in a 16-week rhythmic movement intervention.

The thesis followed a research article format. Article one addressed both objectives of the study. A positive treatment effect on the bio-motor skills was found because was a statistically significant increase in performance after treatment was implemented, based on the treatment-order and treatment time-interaction ($p=\leq 0.05$). The major finding of this study was that when treatment was implemented a statistically significant difference was observed in the bio-motor skills. Among these bio-motor skills were agility, power, local muscular endurance and some dynamic balance directions. The results among the entire population showed that power[1 & 2] (seated medicine ball throw and vertical jump) and local muscular endurance[2, 3 & 4] (2-minute crunch, pull-up to failure and single leg squat to failure), as well well some dynamic balance directions (anterior, anteromedial, posteromedial, posterior, posterolateral direction and medial) improved significantly. Furthermore, among forwards and backs, agility[1] (illinois

without ball) and power[1] (seated medicine ball throw) showed statistically significant improvements ($p=\leq 0.05$).

In summary, among the entire sample of participants, power[1, 2] and local muscular endurance[2,3,4] ,as well some dynamic balance directions (anterior, anteromedial, posteromedial, posterior, posterolateral direction and medial), showed statistically significant improvements ($p=\leq 0.05$) from pre- to post-treatment. Amongst forwards and backs, agility[1] and power[1] showed statistically significant improvements ($p=\leq 0.05$). Rhythmic movements can be adapted in various ways in terms of music and movements to accommodate not only the rugby players, but also rugby-orientated movements. Additionally, a rhythmic movement intervention can be used right throughout the season with adaptations to intensity according to the demands of the training phase. For this reason, multiple bio-motor skills can be trained simultaneously, which is advantageous to a demanding rugby-training schedule. In other words, rhythmic movements can be used as a tool to warm-up, as a conditioning method to improve specific bio-motor skills or, when required, as a recovery method for players.

It is recommended that, in order to observe benefits from a rhythmic movement intervention, the rhythmic movement should include and cater for the positional demands of rugby players. Furthermore, the rhythmic movement intervention should be implemented throughout the entire rugby season in order to be as effective as possible. Literature has shown physical, psychophysical and ergogenic benefits of music on performance. Therefore, it is recommended that rhythmic movements be used as an alternative training method during off-season (or detraining phases), and as a recovery method. A rhythmic movement intervention, such as this will assist coaches and trainers, who are frequently searching for new novel ways to improve performance, to implement an alternative training strategy to their strength and conditioning programmes.

OPSOMMING

Die insluiting van ander nie-tradisionele benaderings in afrigting het in rugby kondisionering meer populêr geword. Ritmiese beweging, ook verwys na as "dans", behels die uitvoering van verskillende motoriese vaardighede, die integrasie en volgorde van aksies tussen die ledemate, tydsberekening en ruimtelike presisie. Dit verg die uitvoering van bewegingstake op ouditiewe ritmiese patrone en as 'n veelsydige aktiwiteit wat afhanklik is van 'n groot aantal elemente met direkte en indirekte effekte op die fisiologiese en fisieke eienskappe van 'n speler. In terme van rugby kondisionering dikteer algemene oortuiging dat hierdie fiksheids- of kondisioneringselemente deur gefokusde, geïsoleerde inoefeningsblokke ontwikkel moet word. Uit die huidige literatuur blyk dit duidelik dat die tegniese, taktiese en fisieke kondisionering vir rugby primêr uit tradisionele, rugby-gebaseerde benaderings tot inoefening bestaan. Hoewel, om die mededingende voordeel te behou moet rugby afrigters en spesialis afrigters gereeld nuwe innoverende maniere vind om hulle inoefeningsmetodes en programme aan te pas om sodoende die veranderinge in die profiel van die spel te akkommodeer.

Die primêre doel was om die effek van 'n ritmiese beweging intervensie op geselekteerde bio-motoriese vaardighede van rugby spelers in die Westelike Provinsie Rugby Unie Akademie na te vors. Die eerste doelwit van die studie was om die effek van 'n 16-week ritmiese beweging intervensie op lenigheid, dinamiese balans, ratsheid, krag en lokale spieruithouvermoë van hierdie rugby spelers te ondersoek. Die tweede doelwit was om die geselekteerde bio-motoriese vaardighede van agter- en voorspelers na afloop van deelname aan 'n 16-week ritmiese beweging intervensie te vergelyk.

Die tesis is volgens 'n artikel formaat gestruktureer. Artikel een het beide doelwitte aangespreek. 'n Positiewe behandelingseffek op die bio-motoriese vaardighede is bekom aangesien 'n statisties betekenisvolle behandelingseffek na afloop van die behandeling verkry is, gebaseer op die behandelingsvolgorde en behandeling tyd-interaksie ($p=\leq0.05$). Die grootste bevinding van hierdie studie was dat met die implementering van die behandeling 'n statisties betekenisvolle verskil in die spesifieke bio-motoriese waargeneem is. Onder hierdie bio-motoriese vaardighede was ratsheid, krag, lokale spieruithouvermoë en sommige dinamiese balans rigtings. Die resultate onder die hele populasie het getoon dat krag[1 & 2] (sittende medisyne bal gooi en vertikale sprong) en lokale spieruithouvermoë[2, 3 & 4] (2-minuut opsitte, optrek tot faal en eenbeen hurk tot faal), asook sommige dinamiese balans rigtings (anterior, anteromediaal, posteromediaal, posterior, posterolateraal rigting en mediaal). Voorts,

tussen die voor- en agterspelers het ratsheid[1] (illinois sonder bal) en krag[1] (sittende medisyne bal gooi) statisties beduidende verbeterings getoon ($p=\leq 0.05$).

Om op te som, onder die hele steekproef het krag[1, 2] en lokale spieruithouvermoë[2,3,4], asook sommige dinamiese balans rigtings (anterior, anteromediaal, posteromediaal, posterior, posterolateraal rigting en mediaal), statisties betekenisvolle verbeterings ($p=\leq 0.05$) van pre- tot post-behandeling getoon. Tussen voor- en agterspelers het ratsheid[1] en krag[1] statisties betekenisvolle verbeterings ($p=\leq 0.05$) getoon. Ritmiese beweging kan op verskillende maniere aangepas word in terme van musiek en beweging om nie net rugby spelers te akkommodeer nie, maar ook rugby georiënteerde bewegings. Addisioneel, ’n ritmiese beweging intervensie kan reg deur die seisoen met aanpassing aan intensiteit na aanleiding van die eise van die inoefeningsfase gebruik word. Om hierdie rede kan veelvuldige bio-motoriese vaardighede gelyktydig ingeoefen word wat voordelig is vir ŉ veeleisende rugby inoefening sessie. Met ander woorde, ritmiese beweging kan gebruik word as ’n hulpmiddel vir opwarming, as ŉ kondisionerings metode om spesifieke bio-motoriese vaardighede te verbeter of, wanneer nodig, as ŉ herstel metode vir spelers.

Daar word aanbeveel dat om die voordele van ŉ ritmiese beweging intervensie waar te neem, moet die ritmiese bewegings posisionele eise van rugby spelers ingesluit en daarvoor voorsiening gemaak word. Verder moet die ritmiese beweging intervensie dwarsdeur die hele rugby seisoen toegepas word om sodoende so effektief as moontlik te wees. Die literatuur toon fisieke, psigo-fisieke en ergogeniese voordele van musiek tydens deelname. Daarom word aanbeveel dat ritmiese beweging as ’n alternatiewe inoefeningsmetode tydens die af seisoen gebruik word (of tydens die tydperk van verlies aan opleidingseffek), en as ŉ herstel metode. ’n Ritmiese beweging intervensie soos hierdie sal afrigters en opleiers, wat gereeld na nuwe maniere soek om prestasie te verbeter, help om alternatiewe inoefening strategieë vir hulle krag en kondisioneringsprogramme te bekom.

TABLE OF CONTENTS

DECLARATION	ii
ACKNOWLEDGEMENTS	iii
DEDICATION	iv
SUMMARY	v
OPSOMMING	vii
TABLE OF CONTENTS	ix
LIST OF TABLES	xi
LIST OF FIGURES	xii
LIST OF ABBREVIATIONS	xiii
APPENDICES	xiv

CHAPTER ONE

1.1	INTRODUCTION	16
1.2	PROBLEM STATEMEN	18
1.3	PRIMARY AIM AND SPECIFIC OBJECTIVES OF THE STUDY	18
1.4	MOTIVATION FOR THE STUDY	19
1.5	RESEARCH HYPOTHESIS	19
1.6	STRUCTURE OF THE THESIS	20
1.7	REFERENCES	21

CHAPTER TWO

2.1	INTRODUCTION	27
2.2	RUGBY UNION	28
2.2.1	History and background	29
2.2.2	Positional Requirements	29
2.2.3	Physical Demands	31
2.3	BIO-MOTOR SKILLS	37
2.3.1	Background	37
2.3.2	Flexibility	39
2.3.3	Dynamic balance	40
2.3.4	Agility	41
2.3.5	Power	41
2.3.6	Local muscular endurance	42
2.4	RHYTHMIC MOVEMENT AND BIO-MOTOR SKILLS	43
2.5	RHYTHMIC MOVEMENT	43
2.5.1	Background	43
2.5.2	Benefits of Rhythmic Movement Interventions	44
2.5.3	Rhythmic Movement Interventions	46
2.6	TRAINING METHODS	48
2.6.1	Background	48
2.6.2	The Traditional approach to rugby training	49
2.6.3	Non-traditional approaches to rugby training	50
2.7	SUMMARY	52
2.8	REFERENCES	53

CHAPTER THREE

3.1	INTRODUCTION	69
3.2	STUDY DESIGN	69
3.3	PARTICIPANTS	70
3.4	EXCLUSION AND INCLUSION CRITERIA	70
3.5	DATA COLLECTION PROCEDURE	71
3.6	PRE- AND POST-TESTING PROTOCOL	71
3.7	INTERVENTION	76
3.8	STATISTICAL ANALYSIS	77
3.9	ETHICAL CLEARANCE	77
3.10	DATA STORAGE	77
3.11	DISSEMINATION OF MATERIAL	77
3.12	IMPLEMENTATION OF FINDINGS	78
3.13	REFERENCES	79

CHAPTER FOUR

TITLE PAGE		84
Abstract		85
ABSTRACT		88
4.1	INTRODUCTION	85
4.2	METHODS AND MATERIALS	87
4.2.1	Study Design	87
4.2.2	Participants	87
4.2.3	Procedures	88
4.3	STATISTICAL ANALYSIS	89
4.4	RESULTS	89
4.5	DISCUSSION	97
4.5.1	Practical Application	99
4.6	CONCLUSIONS	99
4.7	ACKNOWLEDGEMENT	100
4.8	DISCLOSURE OF INTEREST	101
4.8.1	Disclosure of interest	101
4.9	REFFERENCES	101

CHAPTER FIVE

5.1	SUMMARY	109
5.2	CONCLUSIONS	110
5.3	LIMITATION	111
5.4	FUTURE RESEARCH	112
5.5	REFERENCES	113

LIST OF TABLES

Chapter 2

Table 2.1 Positional names and positional groups of 15's rugby 29

Table 2.2 Studies identifying physical and positional demands of rugby players 34

Chapter 3

Table 3.1 Exclusion and Inclusion criteria 70

Table 3.2 Description of test used in the study 73

Chapter 4

Table 4.1 Participant characteristics. 88

Table 4.2 Bio-motor skills which showed a statistically significant difference (p=≤0.05) when comparing pre- and post-control (no treatment), and pre- and post-treatment (M ± SD) in the different treatment groups (CT and TC). 90

Table 4.3 Bio-motor skills which showed a statistically significant difference (p=≤0.05) when comparing pre- and post-control (no treatment), and pre- and post-treatment (M ± SD) when comparing Forwards and Backs. 92

Table 4.4 Bio-motor skills which did not show a statistically significant difference (p=>0.05) when comparing pre- and post-control (no treatment), and pre- and post-treatment (M ± SD) in the different treatment groups. 93

Table 4.5 Bio-motor skills which showed a statistically significant difference (p=≤0.05) when comparing pre- and post-control (no treatment), and pre- and post-treatment (M ± SD) when comparing forwards and backs. 95

LIST OF FIGURES

Chapter 3

Figure 3.1 Cross-over experimental research design 70

Chapter 4

Figure 4.1 Timeline for the study 88
Figure 4.2: Star Excursion Balance test (SEBT) statistically significant means for each reach direction between Control and Treatment time periods. 91
Figure: 4.3: Star Excursion Balance test (SEBT) means for each reach direction, which did not show a statistically significant difference (p>0.05). 94

LIST OF ABBREVIATIONS

SANZAR	South Africa, New Zealand and Australian Rugby
WPRU	Western Province Rugby Union
GPS	Global Positioning Systems
CODS	Change-of-direction-speed
RAT	Reactive-agility-test
REA	Repeated-effort ability
ACL	Anterior cruciate ligament
LS	Linear speed
RHIE	Repeated high-intensity effort
DMT	Dance Movement Therapy
SEBT	Star Excursion Balance Test
BPM	Beats Per Minute (bpm)
CT^B	Control-treatment^B
TC^A	Treatment-control^A

APPENDICES

A. Informed consent form

B. Testing Protocol

C. Rhythmic movement intervention session's weeks 2-9 and weeks 16-23

D. Ethical clearance letter

E. Manuscript Submission Guidelines: Journal of Sports Sciences

CHAPTER 1

INTRODUCTION AND PROBLEM STATEMENT

This chapter is included herewith in accordance with the referencing style of the Department Sport Science, Stellenbosch University.

1.1 INTRODUCTION 16

1.2 PROBLEM STATEMENT 18

1.3 PRIMARY AIM AND SPECIFIC OBJECTIVES OF THE STUDY 18

1.4 MOTIVATION FOR THE STUDY 19

1.5 RESEARCH HYPOTHESIS 19

1.6 STRUCTURE OF THE THESIS 20

1.7 REFERENCES 21

1.1 INTRODUCTION

Rugby union (referred to as rugby) is one of the most popular team contact sports in the world. Rugby is known for its intermittent contact, exposing players to short-duration, high-intensity activities, such as high-speed running, sprinting, collisions and tackling along with longer periods of activity at lower intensities and rest periods (Cahill *et al*., 2013:230; McLaren *et al*., 2016:494; Cunningham *et al*., 2016:2; World Rugby, 2019). Rugby is played for 80 minutes (2 halves of 40 minutes each), between two teams made up of 15 players each, excluding the allowed replacements (typically 8 at international and professional level) (Lombard *et al*., 2015; World Rugby, 2019). The 15 players are divided into two general positional groups, namely “forwards” and “backs”, with players from the jersey numbers one to eight and nine to 15 making up the forwards and backs respectively (World Rugby, 2019).

Players have become faster, stronger, more powerful and clinical (playing with pace and skilful precision) in implementing the physical attributes of rugby within the laws of the game (Lacome *et al*., 2014:292; Cunningham *et al*., 2016:2 ; Read *et al*., 2017:1291). As in any other team sports, it requires specific characteristics for each position based on physical stature, speed and skills (Lindsay *et al*., 2015:483-484). Therefore, it is important for players to train and execute specific bio-motor skills, which can include: speed; endurance; strength; balance; coordination; and flexibility (Bompa & Buzzichelli, 2018:93). These bio-motor skills in rugby form the foundation of the broader positional specific skills, which players need to train for and execute (Sirotic *et al*., 2011:3084-3086; Lindsay *et al*., 2015:482). Quarrie *et al*. (2013:357-358) notes that the physical demands of rugby are related to the activities of the positional role, which the player is required to fulfil. With this being said, a range of bio-motor skills are required to withstand the collisions during both attacking and defensive play stages of the game (Gabbett *et al*., 2014:558). Thus, as far as the physical demands of rugby are concerned, there is clear evidence of the variation of amounts of movement patterns, contact loads and activities between positional groups. These variations imply a need for different conditioning regimes aimed specifically at the various positional groups (Quarrie *et al*., 2013:358; Jones *et al*., 2015:488).

Technical, tactical and physical conditioning for rugby has primarily comprised traditional rugby-based approaches to training. Examples of rugby-based approaches include: resistance-based training (which entails training for muscular strength and power); agility and change-of-direction speed training; plyometric training and speed; agility training; and small-sided games

(Corcoran & Bird ., 2009:67; Harrison & Bourke, 2009:275; Wheeler *et al*., 2010:445; Kennett *et al*., 2012:2038; Tobin & Delahunt, 2014:367-368; Young *et al*., 2015:161; Gannon *et al*., 2016:382; Speirs *et al*., 2016:388). These approaches are based on the belief that all it should develop the fitness elements through focused, isolated training blocks (Haff, 2016:404; Bompa & Buzzichelli, 2018:93). In reality, however, competition structure dictates that these qualities should be developed concurrently (Tee *et al*., 2018:2-4). This has led to coaches applying tactical periodization within elite rugby union, which is based on the principle that training should never be separate, but that the physical, tactical, technical and psychological elements of preparation should all be developed holistically (Delgado-Bordonau & Mendez-Villanueva, 2012:28; Tee *et al*., 2018:2-4). The inclusion of other non-rugby related activities and cross-training has become more popular within the rugby strength and conditioning field; rugby teams draw from other sports as means of training, such as athletics (for speed training techniques), volleyball, handball, soccer and basketball. These sports are used for high intensity movements, passing, speed and fitness, as well as plyometric training (Vaz *et al*., 2013:225-226).

A more specific example of the use of rhythmic movement in sport is that of soccer, which has implemented rhythmic movement interventions to improve bio-motor skills (Gard, 2006:63; Dyke, 2015:35). Rhythmic movement activities have been explored in literature and are described as involving the execution of different motor skills, integration and sequencing of actions between limbs, timing and spatial precision (Gard, 2006:63; Bertollo *et al*., 2010:79; Alpert, 2011:155; Dyke, 2015:35). Interestingly, rugby players can be seen executing a form of rhythmic movement in practise or competition; from the duet performed between the lifters and jumpers in the line-out, the scrummaging formations, to strategically timed tackles and critical displays of agility and speed to advance toward the try line (Gabbett *et al*., 2014:558). Alpert (2011:156) refers to the many benefits of rhythmic movement, which include increased muscle strength and tone, endurance, flexibility and range of motion, balance and spatial awareness and an overall feeling of well-being. Studies based on rhythmic movement interventions amongst athletic populations, reported positive effects on cardiovascular fitness, lung function and flexibility along with positive impacts on areas of confidence, social health and emotional well-being (Huebscher *et al*., 2010:415; Dyke, 2015:35).

To gain the competitive edge over opposing teams, rugby coaches, specialist coaches (including strength and conditioning coaches, as well as technical and tactical coaches), frequently need to adapt their training methods and programmes to accommodate and take advantage of the physical, technical and tactical changes to the profile of the game (Austin *et al*., 2011:261; Hartwig *et al*., 2011:16; Handcock & Cassidy, 2014:42-43; Jones *et al*., 2016:5-6). The science of examining rugby and its role players' performance (coaches, players and referees), has grown rapidly to meet the increasing demand for knowledge on the technical, tactical, physical and psychological components of the game (Bangsbo *et al*., 2006:2-3; Quarrie *et al*., 2017:2-4). The assumption is that an athletic population such as rugby players, who also need to show a complexed interaction of the same bio-motor skills as dancers and soccer players, would also benefit from a rhythmic movement intervention.

1.2 PROBLEM STATEMENT

Coaches, along with other specialist coaches (strength and conditioning coaches, as well as technical and tactical coaches), are looking for new ways to improve rugby performance. Unfortunately, there is a paucity of published research concerning the use of rhythmic movement in rugby. Therefore, the current study aspires to explore the effect of a rhythmic movement intervention on rugby-specific bio-motor skills of academy rugby players.

1.3 PRIMARY AIM AND SPECIFIC OBJECTIVES OF THE STUDY

The primary aim was to investigate the effect of a rhythmic movement intervention on selected bio-motor skills of academy rugby players in the Western Province Rugby Union.

The specific objectives were:

- To investigate the effect of a 16-week rhythmic movement intervention on flexibility, dynamic balance, agility, power and local muscular endurance of academy rugby players in the Western Province Rugby Union.
- To compare selected bio-motor skills of backs and forwards after participating in a 16-week rhythmic movement intervention.

1.4 MOTIVATION FOR THE STUDY

In rugby, specific bio-motor skills, and therefore, the ability to improve these abilities play a key role in the performance of the sport. Research, specially done on only rhythmic movement and its effect on a sport such as soccer, has shown that a rhythmic movement intervention can have benefits on bio-motor skills of the particular sport. Due to the transferability of movement qualities between rugby and dance-sport, the participants will acknowledge the merit of a rhythmic movement intervention and its effect on bio-motor skills in the sport of rugby.

1.5 RESEARCH HYPOTHESIS

After participating in a 16-week rhythmic movement intervention, selected bio-motor skills of academy rugby players in the Western Province Rugby Union will improve.

- *H_1:* A 16-week rhythmic movement intervention will improve selected bio-motor skills, such as flexibility, dynamic balance, agility, power and local muscular endurance of academy rugby players in the Western Province Rugby Union.
- *H_0:* A 16-week rhythmic movement intervention will not improve selected bio-motor skills, such as flexibility, dynamic balance, agility, power and local muscular endurance of academy rugby players in the Western Province Rugby Union.

Subsequent to participating in a 16-week rhythmic movement intervention, there will be a difference in improvement between the backs and forwards in terms of selected rugby-specific bio-motor skills.

H_1: There will be a difference in terms of improvement between the selected bio-motor skills of backs and forwards after participating in a 16-week rhythmic movement intervention.

H_0: There will be no difference in terms of improvement between the selected bio-motor skills of backs and forwards after participating in a 16-week rhythmic movement intervention.

1.6 STRUCTURE OF THE THESIS

The thesis is presented in a research article format. One research article (Chapter Four), was prepared according to the guidelines of the specific journal (Appendix E). The referencing style used in the different chapters of this thesis will differ.

Chapter One: Introduction and problem statement: The chapter made use of an adapted Harvard method of referencing in accordance with the guidelines of the Department of Sport Science, Stellenbosch University.

Chapter Two: Theoretical context: The chapter made use of an adapted Harvard method of reference in accordance with the guidelines of the Department Sport Science, Stellenbosch University.

Chapter Three: Methodology: The chapter made use of an adapted Harvard method of reference in accordance with the guidelines of the Department of Sport Science, Stellenbosch University.

Chapter Four: Research article: The effect of a rhythmic movement intervention on selected bio-motor skills of Western Province Rugby Union academy players. This chapter was structured according to the guidelines of the Journal of Sports Sciences (Appendix E).

Chapter Five: Summary, limitations and future research.

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CHAPTER 2
THEORETICAL CONTEXT

This chapter is included herewith in accordance with the referencing style of the Department Sport Science, Stellenbosch University.

2.1 Introduction	**27**
2.2 Rugby Union	**28**
2.2.1 History and background	28
2.2.2 Positional Requirements	29
2.2.3 Physical Demands	31
2.3 Bio-motor skills	**37**
2.3.1 Background	37
2.3.2 Flexibility	39
2.3.3 Dynamic Balance	40
2.3.4 Agility	41
2.3.5 Power	41
2.3.6 Local muscular endurance	42
2.4 Rhythmic movement and bio-motor skills	**43**
2.5 Rhythmic Movement	**43**
2.5.1 Background	43
2.5.2 Benefits of rhythmic movement interventions	44
2.5.3 Rhythmic movement interventions	46
2.6 Training Methods	**48**
2.6.1 Background	48
2.6.2 The traditional approach to rugby training	49
2.6.3 Non-Traditional approaches to rugby training	50

2.7 Summary 52

2.8 References 53

2.1 Introduction

Rugby union (hereafter referred to as rugby) is one of the most popular team contact sports in the world and known for its intermittent contact. It exposes players to short-duration, high-intensity activities such as high-speed running, sprinting, collisions and tackling along with longer periods of activity at lower intensities and rest periods during match-play (Cahill *et al.,* 2013:230; McLaren *et al.,* 2016:494; Cunningham *et al.,* 2017:2; World Rugby, 2019). Players essentially all perform some type of rhythmic movement in practise or match-play; from the duo performed between the lifters and jumpers in the line-out, the scrummaging formations, to strategically timed tackles and critical displays of agility and speed to get to the try line (Gabbett *et al.,* 2014:558). Rugby players have thus become faster, stronger, more powerful and clinical (playing with pace and skilful precision) in implementing the physical attributes of rugby within the laws of the game (Lacome *et al.,* 2014:292; Cunningham *et al.,* 2016:2; Read *et al.,* 2018:646) Thus, it is important for all players to train and execute specific bio-motor skills during training and match-play. These include speed, endurance, strength, balance, coordination and flexibility (Bompa & Buzzichelli, 2018:93).

In order to gain the competitive edge over opposing teams, rugby coaches and specialist coaches frequently need to adapt their training methods and programmes to accommodate and take advantage of these changes to the profile of the game (Austin *et al.,* 2011:261; Hartwig *et al.,* 2011:16; Handcock & Cassidy, 2014:42-43; Jones *et al.,* 2016:5-6). In rugby, the above-mentioned bio-motor skills form the foundation of the broader positional specific skills which players need to train for and execute (Sirotic *et al.,* 2011:3084-3086; Lindsay *et al.,* 2015:482). Rugby, furthermore, demands of players to develop and execute short repeated sprints, quick changes of direction and rapid acceleration along with producing high muscle force (Lindsay *et al.,* 2015:485). Thus, due to players experiencing frequent bouts of high-intensity activity (for example sprinting and tackling) with short bouts of low-intensity activity (for example walking and jogging), along with contacts, the inclusion of these skills for player conditioning prove to be important throughout the rugby season (De Lacey *et al.,* 2014:2373).

Currently, the majority of research based on training methods for rugby players, focuses on the traditionally rugby conditioning as a means to improve technical, tactical and physical conditioning (Gabbett & Jenkins, 2010[b]:578; Gabbett *et al.,* 2012:488; Phibbs *et al.,* 2017:180-181). Some of these conventional training methods include, "on-side off-side games" (Gabbett & Jenkins, 2010[b]:2980) pre- and in-season skills training sessions using micro technology

(Gabbett *et al.,* 2010[b]:279), along with small-sided conditioning games aimed at improving rugby specific fitness (Kennett *et al.,* 2012:2038; Weaving *et al.,* 2014:905). Additionally, standard common methods of training include the use of resistance-based training (Corcoran *et al.,*2009:67; Harrison & Bourke, 2009:275) which includes training for strength and power (Gannon *et al.,* 2016:382), agility and change-of-direction speed training (Wheeler *et al.,* 2010:445; Young *et al.,* 2015:161), concurrent speed and resistance training (Suarez-Arrones *et al.,* 2014:667) and concurrent strength and endurance training (Baker *et al.,*2011:8; Jones *et al.,* 2016:3353). These are all means of training related to rugby-specific movements and bio-motor skills.

According to the researchers, there is currently no published literature available which specifically focuses on the inclusion of rhythmic movement as a means for training and improving performance, of rugby players. This chapter aims to review the available literature and is presented in the following four sections: (1) an introduction to rugby as well as its history and background, (2) the physical demands of rugby and positional specific requirements, (3) specific bio-motor skills as it relates to rugby and (4), the use of rhythmic movement as a non-traditional approach to improve specific bio-motor skills of rugby players.

2.2 Rugby Union

2.2.1 History and background

The common held belief of the founding of rugby dates back to 1832, when a school pupil named William Webb Ellis, picked a football up and began to run with it. This act of picking up the ball as opposed to kicking it, gave rugby its distinguishing feature as we know it today (Bolligelo, 2006:7; Richards, 2011:1886). The laws of the game came into existence once school rugby drafted laws regarding the lines of decisions, based on disputed points (Richards, 2011:1886). Many years later, rugby continued to grow into an amateur sport and eventually became acknowledged as a professional sport in 1995, because players received remuneration. This shift lead to the formation of SANZAR (South Africa, New Zealand and Australia Rugby), currently known as Super Rugby (Higham & Hinch, 2003:236; Bolligelo, 2006:7; Kenelly *et al.,* 2014:407; Lindsay *et al.,* 2015:481). Today, World Rugby serves as the governing body of the game, which is played worldwide in over 100 countries and across five continents, annually (World Rugby, 2019).

Modern day rugby is known by its increased playing intensities (for example, ball in play time and speed of play) along with injury rates, both of which are directly associated with the level of contact rugby players endure (Read *et al.,* 2018:645-646). Evidence suggests that rugby has become faster and more physically demanding (Lombard *et al.,* 2015; Jones *et al.,* 2018:2399). It is not solely the trends of match play that are changing, but the physical characteristics of players too (Read *et al.,* 2018:649).

2.2.2 Positional requirements

Rugby is played for 80 minutes (2 halves of 40 minutes) between two teams made up of 15 players each, excluding the authorised replacements (typically 8 at international and professional level) (Lombard *et al.,* 2015:980; World Rugby, 2019). The 15 players are divided into two general positional groups, namely "forwards" and "backs", with players from the jersey numbers 1-8 and 9-15 making up the forwards and backs respectively as shown in Table 2.1 below (World Rugby, 2019).

TABLE 2.1: **POSITION NAMES AND POSITIONAL GROUPS OF FIFTEENS RUGBY**

Jersey number	Position name	General positional group 1	Positional group 2
1	Loose-head prop	Forwards	Tight 5
2	Hooker		Tight 5
3	Tight-head prop		Tight 5
4	Lock		Tight 5
5	Lock		Tight 5
6	Flank		Loose trio
7	Flank		Loose trio
8	Number 8		Loose trio
9	Scrum-half	Backs	Inside backs
10	Fly-half		Inside backs
12	Inside centre		Inside backs
11	Left wing		Outside backs
13	Outside centre		Outside backs
14	Right back		Outside backs
15	Full-back		Outside backs

Note: Adapted from Anon (2019:1)

With these distinctive game characteristics, as determined by positional requirements, come distinctive roles and responsibilities. Vaz et al. (2013) states that training tasks should be structured and planned in accordance with the competition demands and the players' positional requirements. In some sports this is relatively easy to accomplish given that all the team players are required to perform similar tasks; this is not the case for rugby (Vaz et al., 2013:3-4; Read et al., 2018:645). The forwards and backs are assigned functional roles to perform during match play. However, the significant development of physical attributes by all playing positions and the introduction of new law changes aimed at enhancing the appeal of the game, have resulted in a shift towards integrating these roles (Jarvis *et al.,* 2009:218; Fuller *et al.,* 2013:795-796 ; Read *et al.,* 2018:645).

Studies using Global Positioning Systems (GPS) technology (Coughlan *et al.,* 2011:602-603; Cahill *et al.,* 2013) have identified positional requirements (Austin *et al.,* 2011:281; Read *et al.,* 2018:645-6). Two specific studies using GPS (Austin *et al.,* 2011:281; Cahill *et al.,* 2013:230) showed that forward players have the highest involvement in defensive skill movements similar to Sirotic et al. (2011:3084). According to Sirotic *et al.* (2011), forwards find themselves executing the most tackles and tackle wins during a match compared to the backs. Compared to backs, the front row also experiences sustained higher contact loads per match due to activities as tackles, rucks and mauls (Quarrie *et al.,* 2013:358-9). Thus, tackles are often regarded, by players, as one of the most physically exhausting skills in the game (Sirotic *et al.,* 2011:3084). Additionally, forwards' traditionally short, high-intensity bouts of activity to compete for the ball, incorporates longer sprint durations with the ball in open play, along with more evasive manoeuvres and handling skills (Sirotic *et al.,* 2011:3076; Gabbett *et al.,* 2014:558). More specifically, the locks (numbers 4 and 5) require a larger body mass and optimal strength, with the blind-side (number 6) and open-side flank (number 7) and number 8 requiring strength and power in order to retain and turn over possession (Gabbett *et al.,* 2014:558-559). Furthermore, upper body strength has been shown to be important in all the playing positions, with the forwards having greater strength in the upper-body versus the backs, with greater lower-body power (Kirkpatrick & Comfort, 2013:2414). Although power is required to break through tackles, it also provides a foundation for speed and assists in the jump during line-outs in order to gain possession of the ball (Croft *et al.,* 2011:2). The loose trio (6, 7 and 8) tend to complete the greatest workload; this suggests that it is one of the fittest and physically demanding positions as shown by Lacome *et al.* (2014:291-292). It is considered highly beneficial, for loose forwards to train for muscle hypertrophy, strength and power in order to withstand the demands of high force and frequent collisions (Usman *et al.,* 2011:547; Lindsay *et al.,* 2015:485-486).

The backs, which are generally smaller in physique, are expected to run at high speeds and advance their team (Lindsay *et al.,* 2015:486). They require speed, change of direction and handling ball skills. However, with the increased need for securing possession of the ball, there is the additional demand of strength, particularly in the upper body (Austin *et al.,* 2011:262; Quarrie *et al.,* 2013:356). Outside-backs (11, 13, 14 and 15) are the specific players for the role of gaining territory and scoring match points, whereas the scrum-halves are involved in physical contact situations (Corcoran, 2009:68; Quarrie *et al.,* 2013:358). Furthermore, inside backs (9, 10 and 12) direct the team's play and they take on a vital decision-making role during attack-play. The inside backs are required to endure high intensity contact with the opposition in defence and attack situations, as they are responsible for handling and passing the ball to create space for their outside-backs to score (Quarrie *et al.,* 2013:356). Furthermore, the full-back fulfils the role of directing defensive set-ups and covers the try-line from kicks (Hulin *et al.,* 2015:488). This player needs to be a support ball carrier during attacking play (Sirotic *et al.,* 2011:3085; Hulin *et al.,* 2015:485).

From the evidence above and in agreement with findings from Quarrie *et al.* (2013:359), it is evident that each position has specific functional roles as well as bio-motor skill requirements and therefore, requires specific fitness and conditioning components to suite these various positional requirements.

2.2.3 Physical demands

Semi-professional and professional rugby players participate in matches extensively throughout the year. These fixtures range from local club rugby matches to provincial matches (for example Super Rugby competition) as well as international matches as far as the professional players are concerned (Tierney *et al.,* 2018:16). The science of examining rugby and its role players' performance (coaches, players and referees) have grown rapidly to meet the increasing demand for knowledge on the technical, tactical, physical and psychological components of the game (Wheeler *et al.,* 2011:394; Sewry *et al.,* 2015:1116; Delaney *et al.,* 2015:2688; Higham *et al.,* 2015:235). These elements are closely linked to each other, e.g., the technical quality of a player may not be optimally utilised if the player's tactical knowledge is limited (Evans, 2012:219; Evans, 2013:145; Mckay & O'Connor, 2018:274-275).

Rugby encompasses various forms of fitness elements, which need to be trained both on and off the field throughout the rugby season, because of the demanding competitive calendar. The physical demands of rugby are related to the activities of the positional role that the player is required to fulfil (Quarrie *et al.,* 2013:353). Thus, as in any other team sport, specific characteristics are required for each position based on physical stature, speed and skills (Lindsay *et al.,* 2015:485). Rugby players require a range of bio-motor skills in order to withstand the collisions during both attacking and defensive play stages (Gabbett *et al.,* 2014:556). The variation of amounts of movement patterns, contact loads and activities between positional groups imply a need for different conditioning regimes aimed specifically at the various groups (Quarrie *et al.,* 2013: 357-358). Therefore, according to Cross *et al.* (2016), in order to develop and maintain all these fitness components throughout the season and prevention and recovery from sport-related injuries, a periodized conditioning program needs to be implemented by coaches as well as strength and conditioning experts. Coaches, along with specialist coaches should therefore keep these aspects in mind and plan and develop effective training programmes, which in turn, will assist to enhance their players' performance (Quarrie *et al.,* 2013:359).

During typical pre-season training, players work towards increasing aerobic and anaerobic fitness, strength, and power, while simultaneously having to improve body composition (Argus *et al.,* 2010; Windt *et al.,* 2017). Pre-season training for elite rugby players, therefore, consists of high-volume, high intensity movements which incorporates multi-faceted aspects of physical conditioning (Argus *et al.,* 2010:680; Smart & Gill, 2013:708). The training phase is typically very short, and lasts between 2-6 weeks before players are required to compete on a weekly basis (Tavares *et al.,* 2017:143). Players often have limited preparation time in order to prepare sufficiently for the physical aspects of the game (Read *et al.,* 2018:643). Additionally, it leaves inadequate time for coaches along with strength and conditioning coaches, to spend time on- and significantly enhance aspects of players' physical conditioning. As a result, players are placed under high pressure to achieve their conditioning goals by training multiple aspects of performance concurrently, which often leads to compromised physical adaptations and injury (Quarrie *et al.,* 2017:421; Tavares *et al.,* 2017:145).

Cahill *et al.* (2013) performed an investigation with Global Positioning System (GPS) technology, to quantify the movement characteristics of elite rugby players during competitive play and attempted to identify whether position-related differences exist. Amongst other results, through the use of Vmax (the percentage of a player's maximum running speed) classifications, the study showed that backs covered more of their total distance (+35.4%) sprinting compared to forwards, and moved (+36.9%) more in the standing and walking category (classified as <20% Vmax) (Cahill *et al.,* 2013:234). On the other hand, forwards spent (19.8%) more (relative to their total distance) of their movements in the 'striding' (51-80% Vmax) category (Cahill *et al.,* 2013:234). The findings of this study reflected a notable difference in the movement characteristics displayed by the rugby players in specific positional roles. Similarly, Coughlan *et al.* (2011) used GPS technology to monitor and evaluate the physical demands of training and games on players. Results considering time spent in a particular speed zone and frequency of entries into these zones, showed that majority of the game (75%) was spent in lower intensity activities such as standing, walking or jogging with alternative moments of medium to high intensity running activities for the remainder of the game time. Furthermore, the GPS data indicated that backs performed a higher number of high-intensity sprints (74 entries in the 18.0-24.1 km/h speed zone; 16 entries into the 24.1-36.0 km/h speed zone) compared to only 56 and 3 entries from the forwards in the same speed zones respectively (Quarrie *et al.,* 2013:358).

TABLE 2.2: **STUDIES IDENTIFYING PHYSICAL AND POSITIONAL DEMANDS OF RUGBY PLAYERS**

Authors	Title of the study	Sample size and methods used	Findings
Sirotic *et al.* (2009)	A comparison of match demands between elite and semi-elite rugby league competition.	17 elite rugby players from the NRL and 22 semi-elite players from the NSWPL participated in the study. Players were video monitored over two seasons (2004-2005) and each playing position was filmed on one or more occasion during matches (39 NRL and 35 NSWPL). Players were unaware they were video monitored (single blind).	Forwards have the highest involvement in defensive skill movements. Forwards execute the most tackles and tackle wins in a match. Tackling is seen by players as one of the most physically exhausting skills in the game.
Quarrie *et al.* (2013)	Positional demands of international rugby union: Evaluation of player actions and movements.	763 players were video recorded and coded. 90 international matches played by the New Zealand national team (the All Blacks) were recorded over the period of 2004-2010. A semi-automated player-tracking system was used to code 27 of the matches and the players' movement activities.	Front rows experience higher contact loads per match due to tackles, rucks and mauls. Therefore, forwards endure more physical contact than backs. Inside backs require speed-strength and power to endure high-intensity contact Inside backs are responsible for handling and passing the ball in order to create space.
Hulin *et al.* (2015)	Physical demands of match play in successful and less-successful elite rugby league teams.	GPS tracking system was used to track movements of players during 25 rugby league matches. Data for each half of match play was separated into 8 equal periods which represented the most intense phase of match play (peak period), the period after the most intense phase of match play (subsequent period) and the average demands of all other periods (mean period). Two teams were split into a high-success and a low-success group based on their success rates throughout their season.	Outside backs require speed-strength in attacking scenarios and for cover defending. Fullbacks are involved in high to very-high intensity activity and tackling skills. They direct defensive set-ups and cover the try-line from kicks.

Authors	Title of the study	Sample size and methods used	Findings
Lindsay *et al.* (2015)	Positional demands of professional rugby.	37 professional rugby players from a Super 15 franchise participated in the study. 23 of the 37 were selected to play each game. GPS and video analysis were used to track player movements.	Backs are smaller in physique. They are expected to run at high speeds and advance their team.
Read *et al.* (2017)	Physical demands of representative match-play in adolescent rugby union.	112 players participated in the study and were divided into 6 groups according to playing positions (forward and backs) and age groups (U16, U18, and U20). Data was collected from matches between October 2014 and January 2015. Matches were part of the annual competitive fixtures between representative county teams. Physical demands were measured using GPS and a triaxial accelerometer, which assessed locomotor and accelerometer metrics.	When comparing between positions, U18 and U20 backs covered relative greater distances than forwards. Due to defensive structures in place during rugby at older ages, this may explain the greater low-velocity activity. Unclear difference in relative distance covered shows that differences between forwards and backs become more pronounced as age increases. Between position differences for players suggests backs and forwards should prepare differently for, match-play.

Table 2.2 provides insight specifically pertaining to the physical and positional demands as indicated by 5 studies: The forwards are larger in physique and endure more physical contacts than backs (Quarrie *et al.,* 2013:359). This finding is in agreement with Sirotic *et al.* (2009:210-211)) who found that forwards execute the most tackles and tackle wins in a match compared to backs. As a result, forwards experience higher contact loads per match due to activities such as tackles, rucks and mauls (Quarrie *et al.,* 2013:359). Similarly, in a study by Quarrie *et al.* (2013) and Gabbett *et al.* (2014), it was found that due to the contacts experienced by forwards, a good strength base for scrummaging and holding onto the ball in the contact area, is required. Increased upper body strength is also important and beneficial to any player in order to withstand the constant hard impacts and tackles by the opposition (Gabbett *et al.,* 2014:558).

On the other hand, backs are smaller in physique compared to their forward counterparts as far as physical stature is concerned. Studies show that the physical demands of backs is contrary to that of forwards who spend most of their activities in lower intensity zones (Cahill *et al.,* 2013:232; Lindsay *et al.,* 2015:485). It is expected that backs run at high speeds in order to advance their team as mentioned Lindsay *et al.* (2015:485). Therefore, the backs require speed, exceptional change of direction and handling skills; however, with the increased need for securing possession of the ball, there is the additional demand of strength, particularly in the upper body (Jarvis *et al.,* 2009:218; Cahill *et al.,* 2013:232). Quarrie *et al.* (2013:359) found that backs require speed-strength and power in order to endure high-intensity contact during matches. Hulin *et al.* (2015:707-708) found the same physical demand whereby he concluded that backs require speed-strength in attacking scenarios and for cover defending. Additionally, backs are involved in high to very-high intensity and offensive skills (Hulin *et al.,* 2015:707-708). The inside backs require speed-strength and power in order to endure the high intensity contact with the opposition in defence and attack (Quarrie *et al.,* 2013:358-359). In terms of the fly-half's (number 10) position, it is essential that strength and acceleration form part of the physical conditioning base due to constant contact scenarios in the game (Gabbett & Jenkins 2010[a]:208; Cahill *et al.,* 2013:232). Furthermore, the scrum-half, according to Fuller *et al.* (2013:796) speed and strength development is important. Overall, rugby demands of all players to attack repeatedly and defend during a game with maximum force, thus not only is power required to break through tackles and gain possession, but a good aerobic base is essential for sustained and repeated work efforts during the entire 80 minutes of the game as suggested by Schuster *et al.* (2017:260).

According to Quarrie *et al.* (2013:358-359), all positions require players to have flexibility, agility, speed, power and rugby-specific skills. Therefore, as supported by similar findings from Cahill *et* *al.* (2013:232) and others using GPS technology (Corcoran, 2009:66; Usman *et al.,* 2011:547; Croft *et al.,* 2011:2; Lacome *et al.,* 2014:290), reinforce the notion that training programmes for players should reflect these differential physical and positional demands.

2.3 Bio-motor skills

2.3.1 Background

Bio-motor skills refer to five specific skills which are considered important in terms of overall athletic skills development and performance (Bompa & Claro, 2015:13). The core bio-motor skills for required to withstand the demands of rugby, include: flexibility, dynamic balance (specifically), agility, power and local muscular endurance specifically (Bompa & Buzzichelli, 2018:93).

Flexibility can be seen as the total range of motion possible at a specific joint or joints (i.e., shoulder- and hamstring flexibility) (Dursley, 2012). In rugby, it is noted that poor flexibility may inhibit optimal performance and result in unnecessary injury and loss of time on the field (Behm & Chaouachi, 2011:2633). Along with flexibility, comes the importance of balance. Hrysomallis *et al.* (2011:223) explored balance ability and athletic performance in a review of various studies. Balance refers to the ability of an athlete (in this case, rugby player) to maintain a state of stability over the base of support (in other words, keeping the centre of gravity over your two feet), either while stationary (static balance), or moving body segments through space (dynamic balance) (DiStefena *et al.,* 2009:2718; Hrysomallis *et al.,* 2011:223).

The review by Hrysomallis *et al.* (2011:223) compared balance ability of athletes at various competitive levels within the same sporting code and more importantly, considered the influence of balance training on sport performance or motor skills (bio-motor skills) (Hrysomallis *et al.,* 2011:224). Results from the available data from cross-sectional studies, showed that gymnasts had the best balance ability followed by soccer players, swimmers, physically active subjects and basketball players. Despite limited data on the influence of balance training on motor skills of elite athletes, cross-sectional studies concluded that balance training may increase the rate of force development and thus, results in an increase in muscular power and subsequent performance of motor skills such as the vertical jump (Hrysomallis *et al.,* 2011:228). In a framework of Ricotti and Ravaschio (2011: 462), it showed how (break) dance can induce a strong improvement of static balance performance on 9-year-old soccer players during a 6-month period. The additional break dance activity had a strong effect, and it was said to be due to typical exercises of break dance mainly based on the ability to maintain balance and co-ordination on a single- and both legs (Ricotti & Ravaschio, 2011:465).

Agility forms part of the bio-motor abilities as it refers to and includes change-of-direction-speed (CODS), perceptual and decision-making skills and reaction speed. Young *et al.* (2015:159) explores in a study, the difference between agility in invasion sports (defined as including reactive decision-making) and CODS, and furthermore highlights the important implications for sports training. In Serpell *et al.* (2010:2370), the purpose was to develop a reliable and valid agility test for rugby league which placed importance on change of direction speed (CODS), perceptual and decision-making skills and reaction speed. Players from a semi-professional rugby league team were tested twice in a sport-specific reactive agility test (RAT) and CODS test. The RAT group ran towards an unpredictable life-size video of an attacking opponent and had to react to it by changing direction. The CODS group on the other hand, was required to perform the same movement patterns, however; their direction changes were pre-planned (Serpell *et al.,* 2010:2370). Results from the study showed two occurrences: firstly, similarly to Paul *et al.* (2016:421), the RAT developed in the study proved to be both valid and reliable and that the CODS test, although reliable, was not valid because it could not distinguish expert performers from lesser-skilled performers. Secondly, Serpel *et al.* (2010:3270) found that the performance differences on the RAT were due to a difference in perceptual skills and/or reaction ability; thus, testing and training for agility as a bio-motor skill should stress the dimensions of agility and not solely CODS (Serpel *et al.,* 2010:3270). This finding is in agreement with Young *et al.* (2015:158) who stated that correlations between agility and CODS tests showed that these are in fact independent skills which players need to develop. In additional to agility, is the importance of power. Power is understood as the ability to demonstrate maximal or near-maximal strength in the shortest period (Durguerian *et al.,* 2019:18). Considering the development of power in sports, there is a positive relationship between power and strength, and therefore, implies that power requires an emphasis of both force and velocity when being trained (Turner *et al.,* 2012:1594; Durguerian *et al.,* 2019:18).

Unlike other sports such as soccer and field hockey, rugby consists of physical collisions such as tackles and rucks (Sirotic *et al.,* 2009:203; Austin *et al.,* 2011:259; Gabbett *et al.,* 2016:80). Moreover, the physiological demands are complex given the movement patterns and work-to-rest ratios which vary throughout a rugby game (King *et al.,* 2009:213; Sirotic *et al.,* 2009:204; Austin *et al.,* 2011:259). The ability to perform repeated sprints with intermittent tackles is known more commonly and experienced as repeated-effort ability (REA) (Johnston & Gabbett, 2011:2789).

The notion of REA demands was shown in a study from the National Rugby League which indicated that players were required to perform between 0 and 4 repeated-sprints bouts during competition (Sirotic *et al.,* 2009:203; Austin *et al.,* 2011:259). Johnston & Gabbett (2011[b]:2790) concluded that players who are able to maintain sprint performance while executing tackles are more likely to deliver a successful performance. From the latter study's conclusion, it is evident that tackling has a great physiological and functional cost when performed intermittently with repeated-sprints and therefore, the results conclude that exclusively performing repeated-sprints in preparation for the high-intensity repeated effort demands of a match may leave players under prepared for the most demanding phases of play (Johnston & Gabbett, 2011:2789).

Lastly, local muscular endurance is understood as the ability of one or more muscles (groups) to shorten or tighten continuously and remain in a contracted (shortened and tightened) state against resistance (Sedano, 2013:2433). Rugby players find themselves in attacking and defending scenarios throughout the game; local muscular endurance is therefore essential for sustained and repeated work efforts during this time (Schuster *et al.,* 2017:255). Kloubec *et al.* (2010:661) found that in active middle-aged men and women, there were statistically significant increases in hamstring flexibility as well as abdominal endurance and upper-body muscular endurance when exposed to pilates exercise for two 60-minute sessions per week for 12 weeks. The study suggests that individuals are able to improve bio-motor skills such as muscular endurance and flexibility using relatively low-intensity pilates exercises (Kloubec *et al.,* 2010:661)

2.3.2 Flexibility

More recent research revealed that hamstring injuries represent the most common cause of lost playing time in rugby (Bourne, 2015). According to Dursley (2012), such injuries are as a result of inadequate flexibility of the hamstring muscles. Other risk factors to injuring hamstring muscles included an imbalance of strength between hamstrings and quadriceps, fatigue and muscle cooling, high volume training, incomplete rehabilitation and poor conditioning (Thomson, 2014). Dursley (2012) implemented sports massage as an intervention amongst rugby players to see if it would increase hamstring flexibility using the active knee extension test as an assessment method. Results were positive and showed massage had a significant effect ($p<0.05$) on hamstring flexibility in all subjects with an average increase in flexibility of 13.22 degrees (Dursley, 2012). Furthermore, Pramono & Nazrul-Hakim (2011:77) highlighted the importance of assessing flexibility as a part of physical performance test batteries. For example, as part of their physical evaluation, the selected Malaysian national rugby players had to perform the sit-and-reach test which specifically assessed lower back and hamstring flexibility. Findings indicated positive results amongst the participants with an average of 6.6-centimetre increase (Pramono & Nazrul-Hakim, 2011:77). Therefore, it is evident that being relatively flexible can be advantageous, especially during high-impact contact rugby activities such as scrumming, as flexibility is joint specific and therefore helps to reduce the risk of hamstring injury (Aguilar *et al.,* 2011:1130). For this reason, it is important that flexibility training is included in rugby players' pre-conditioning training program alongside strength- and speed and agility training in order to ensure optimal player conditioning and match readiness (Cahill *et al.,* 2013:229).

2.3.3 Dynamic balance

The balance performance of a player is based on their ability to interpret and react to visual, vestibular and proprioceptive inputs while simultaneously maintaining postural stability and control of their movement (Dykes, 2015:3). Thus, dynamic balance is considered more important than static balance regarding athletic performance and injury prevention (Huebscher *et al.,* 2010:413; Zemkova, 2014:579). However, Hammamai *et al.* (2014:38) reported that practicing rugby at an elite level can lead to long-term improvements in static balance performance when compared with sprinters and jumpers in the study. Thus, a recommendation was made to use a variety of exercise to improve balance (Hammamai *et al.,* 2014:38). According to Dykes (2015:2), it is important to determine which athletes demonstrate better dynamic abilities, so that potential benefits of cross-training can be considered. In support of Hrysomallis *et al.* (2011:224), Dykes (2015:3) concluded that soccer athletes and ballroom dancers have similar dynamic balance skills and athletes who wish to improve their balance, may see similar results from training in either soccer or ballroom dance.

Butler *et al.* (2013:417) refers to previous research which suggests that poor dynamic balance may be associated with an elevated risk for injury (Butler *et al.,* 2012:616). It was found that the most common ankle injuries amongst rugby players occur on the lateral side of the foot together with achilles tendon injuries (Pearce *et al.,* 2011:113). It is commonly believed that improved balance can enhance athletic performance and reduce injury risk (Hrysomallis, 2011:228). Therefore, similarly to having better flexibility, improved balance and balance training is said to reduce the number of recurrence in ankle injuries and anterior cruciate ligament (ACL) injuries (Gianotti *et al.,* 2009:372; Pearce *et al.,* 2011:113). Similarly, Chow *et al.* (2016:946) considered balance performance amongst amateur- and non- rugby players and this was evaluated using various balance strategies. The study examined the injury-related factors which may affect players' balance performance. Interestingly so, the rugby group demonstrated poorer balance performance and balance compared to the non-rugby participants. The poor balance performance was due to insufficient training experience and not necessarily with a history of injury (Chow *et al.,* 2016:948). Hrysomallis *et al.* (2011:224) concludes that the ability of having better balance ability implies better sport performance.

2.3.4 Agility

The development of speed along with agility, in the context of a sport such as rugby, becomes particularly important in task-specific movements such as stepping or attacking-play (Wheeler *et al.,* 2010: 238-239). The essential element to optimizing agility is to minimize the loss of speed (slowing down) whilst shifting the body's centre of gravity (Serpell, 2010:3270). Consequently, this movement requires fast directional changes, which are used to give the competitive advantage to an attacker when trying to outmanoeuvre his defender during the specific case of a rugby side-step (Brault *et al.,* 2012:12). Green *et al.* (2011:1256) investigated the reliability and construct validity of a field test protocol for linear speed (LS) and agility in rugby (academy and club players). Trials of 10- and 30-meter linear speed as well as agility, and reactive agility speed (RAS) were measured in order to evaluate the field test protocol's usefulness in distinguishing players of different playing abilities. The results of the study showed that academy players performed significantly ($p<0.05$) faster, in both the LS and agility components, compared to the club players (Green *et al.,* 2011:1257). Furthermore, the study suggests that the specific test battery used is an appropriate measure in identifying the varying playing abilities of rugby union players.

2.3.5 Power

Power becomes particularly important in cases where the player needs to achieve maximum velocity during sprinting, scrums and jumps in lineouts. Lower body power can help to improve sprinting ability through improving general maximal strength (Barr *et al.,* 2014:2585). Argus *et al.* (2012:2698) assessed the difference in strength and power between levels of competition amongst professional and semi-professional rugby union players. Amongst these power tests were the bench press and box squat, bench row (assessing upper-body peak power) and jump squat test (assessing lower-body peak power). The findings of the study revealed that the professional rugby players produced greater absolute and relative strength and power outputs (4 to 51%; small to very large effect sizes) than the semi-professional group (Argus *et al.,* 2012:2670). From these results, Argus *et al.* (2012:2670) concluded semi-professional rugby players, should aim to achieve greater levels of strength and power in order to be physically prepared for the next level of competition such as the case of the professional level rugby players. For these reasons, according to Barr *et al.* (2014:2585), high levels of maximal, explosive, and reactive strength is an important factor for performance in rugby players. This is in agreement with de Lacey *et al.* (2014:2374) who found that backs have similar relative strength in comparison with forwards. The results from de Lacey et al. (2014:2374) were as follows: backs were significantly faster over 10 me (by 3.6%) and 40 meters (by 5.3%) respectively, compared to forwards. Additionally, backs displayed considerably better values than forwards in terms of producing horizontal force (23.3% more) and power relative to body mass (25.4% more). Thus, de Lacey *et al.* (2014:2374) emphasises the notion of Barr *et al.* (2014:2585) and Cunningham *et al.* (2016:4), in that developing force and power in the horizontal direction may be beneficial for improving sprinting performance in professional rugby league players.

2.3.6 Local muscular endurance

It is important that the player has excellent muscular endurance; this will allow the player to withstand the impacts of intermittent collision by opponents and to be able to execute position specific skills, such as scrummaging (scrums, rucks and mauls) and tackling (Austin *et al.,* 2011:260). Hendricks & Lambert (2014:715) examined risk factors for contact injury amongst professional rugby players by looking at the influence of fatigue on tackling ability and the role of muscular strength, endurance and aerobic qualities. Various assessments were executed by the semi-professional rugby league players on speed (10 meter and 40 meter sprint), upper-body strength (4 RM bench press and weighted chin-up), upper-body muscular endurance (body mass maximum repetition chin-up, body mass maximum repetition dips), lower-body strength (4RM squat), and estimated maximal aerobic power (multi-stage fitness test). More importantly, the ability to tackle under fatigue circumstances was tested using a standardized one-on-one tackling test before, during and after four bouts of repeated high-intensity effort (RHIE) exercise (Gabbett *et al.,* 2016:2). While a progressive reduction in tackling ability under fatigue conditions were found after each bout of RHIE, results showed no significant relationship (determined by Pearson product moment correlation coefficients) between tackling ability under conditions of fatigue and other physical quality (Hendricks *et al.,* 2014:716; Gabbett *et al.,* 2016:2). Gabbet *et al.* (2016:6) concludes that these findings suggest lower-body strength prevents fatigue-induced reductions in tackling ability and thus, also injury (Burger *et al.,* 2016). Therefore, as supported in findings by Austin *et al.* (2011:262), the development of lower-body strength should be a priority in players' conditioning in order to help them execute strong tackling skills even while in fatigued circumstances (Hendricks & Lambert*,* 2014:715; Gabbett *et al.,* 2016:2).

2.4 RHYTHMIC MOVEMENT AND BIO-MOTOR SKILLS

Literature concerning bio-motor skills of dancers, have shown how the implementation of traditional training methods of other sports (such as dancers using strength training and plyometric training), can have positive effects on dancers' bio-motor skills. It has been shown that above and beyond normal dance training, dancers utilise other forms of training such as strength and plyometric training (Angioi *et al.,* 2009:475) and the popular whole-body vibration training (Wyon *et al.,* 2010:866; Marshall & Wyon, 2012:789) in order to improve performance.

The effect of strength and plyometric training on functional dance performance was tested amongst elite ballet and modern dancers (Girard *et al.,* 2015:233). In the systematic review of Girard *et al.* (2015), studies found positive effects of strength training on dancers' selected performance measures (generally using free-weights or universal gym) (Twitchett *et al.,* 2011:123). Additionally, the review highlighted studies which showed positive results on the effect of strength and resistance training on vertical jump height (Wyon *et al.,* 2010:866) ,as well as jump height and active range of motion (Marshall *et al.,* 2012). In the case of dance performance specifically, strength training demonstrated positive effects on either vertical jump height or subjective dance performance (Girard *et al.,* 2015:233).

2.5 Rhythmic Movement

2.5.1 Background

Rhythmic movement, also referred to as "dance", involves the execution of different motor skills, integration and sequencing of actions between limbs, timing, and spatial precision (Bertollo *et al.,* 2010:78). It requires performing movement tasks to auditory rhythmic patterns (Bertollo *et al.,* 2010:78). As in any other sport, for dancers, whole body fitness is crucial in terms of reducing the risk of injury, enhancing dance performance and ensuring longer dance careers (Angioi *et al.,* 2009:475; Redding *et al.,* 2009:3; Alpert, 2011:108). It is said that rhythmic movements require from an athlete to demonstrate a proficient level of muscle co-ordination, muscle stamina and strength and aerobic endurance (Koutedakis *et al.,* 2009:157; Mistiaen *et al.,* 2012:381). Redding *et al.* (2009:3) lists and defines the components of fitness in rhythmic movement as: aerobic fitness (moderate, long-term levels of activity), anaerobic fitness (high intensity maximal, short bursts of activity), muscle endurance (ability of a muscle to produce a continuous movement), strength (ability of a muscle to produce a maximal force on one occasion), power (the explosive, speed-related, element of strength), flexibility (the range of motion at a joint in association with the pliability of a muscle), neuromuscular co-ordination (balance, agility, co-ordination and skills), body composition (body weight by percentage of muscle and fat) and rest (a period of inactivity to allow for recovery and regeneration).

2.5.2 Benefits of rhythmic movement interventions

Due to all these fitness components within rhythmic movement activity, it has many physical as well as physiological benefits (Quiroga *et al.,* 2010:149; Alpert, 2011:108; Malkogeorgos *et al.,* 2011). Alpert (2011) refers to the many benefits of dance which include increased muscle strength and tone, increased endurance, increased flexibility and range of motion, balance and spatial awareness and an overall feeling of well-being. Moreover, rhythmic movement is said to be just as beneficial to health as running on a treadmill, jogging around a track, swimming or biking (Alpert, 2011). As a result, dancers' physiology and fitness is just as important as skills development because of the physical demands they need to endure (Angioi *et al.,* 2009:475).

The notion of the benefits of dance has further been explored in literature (Alpert *et al.,* 2009:475; Malkogeorgos *et al.,* 2011; Kiepe & Stockigt *et al.,* 2012:404; Koch *et al.,* 2014:46; Murrock & Graor, 2014:380). A growing interest is seen particularly regarding body-orientated approaches, such as dance movement therapy (DMT) for increasing subjective wellbeing (Koch *et al.,* 2014:46). Findings of Koch *et al.* (2014:46) revealed that dancing is perceived as a multidimensional activity which contributes positively towards several aspects of human well-being; thus alluding to the effectiveness of DMT for increasing health-related aspects and quality of life. DMT participation, furthermore, has the potential to improve higher brain cognitive functioning, as well as the integration of emotional, physical and social determinants of health amongst older adults (Cross *et al.,* 2012:413; Chuang *et al.,* 2015:1181). Additionally, a narrative review of dance-based exercise and its specific impact on depressive symptoms in older adults, revealed that dance therapy has shown to assist such individuals to overcome health problems that lead to physical limitations; these include physical disability as well as psychological distress, including anxiety and depression (Kiepe & Stockigt *et al.,* 2012:404). Furthermore, DMT may be helpful in improving the mobility and functional capacity of older people with arthritis who are unable to endure demanding aerobic exercise (Murrock & Graor, 2014:380). More importantly, researchers have observed that apart from dance inducing relaxation and increasing feelings of subjective well-being, it has the potential to increase balance and motor control and in turn increases motor performance (Alpert *et al.,* 2009155; Cruz-Ferreira *et al.,* 2015:837). Similarly, a case study, involving a healthy non-clinical population and their subjective well-being, indicated that there is a significant improvement in subjective well-being levels and psychological states as a result of DMT (Malkina-Pykh, 2015:106). Another systematic review considered the effects of participating in recreational dance on the physical health and psychosocial outcomes of children and adolescents (Burckhardt & Brennan, 2012:148). Fourteen studies covering a range of different dance disciplines, population groups and settings were included in the review (Burkhardt & Brennan, 2012:148-149) and found that dance may have some positive outcomes on physical and psychosocial well-being. Additionally, Quiroga *et al.* (2010:149) explored the perceived benefits of dancing on wellbeing. Quantitative as well as qualitative analysis showed that dancing has potential positive benefits on wellbeing in several ways, particularly in terms of physical, social and spiritual dimensions of wellbeing (Quiroga *et al.,* 2010:149). This conclusion was in agreement with Malkogeorges *et al.* (2011), which provided an overview of rhythmic movement (dance) for physicians who may evaluate the use of dance-based exercise in their practise (Marks, 2016:61). The study of Malkogeorges *et al.* (2011) showed that rhythmic movement is an excellent means for improving physical fitness and developing social skills, which in turn improves mental health.

In the physical domain and more closely related to rhythmic movement, is the use of yoga amongst many international football, rugby, cricket and golf clubs in countries such as South Africa (Iftekher *et al.,* 2017:276-277). Although not necessarily executed to a specific or strict rhythmic pattern or to music, yoga is considered rhythmic movement because it involves executing various motor skills and co-ordinating actions between limbs (sometimes with music) (Bertello *et al.,* 2010:78; Iftekher *et al.,* 2017:277). Yoga is a highly structured activity that can simultaneously enhance several specific components of fitness and furthermore, mimics critical aspects of athletic performance including balance, flexibility, muscular strength, muscular endurance and co-ordination (Iftekher *et al.,* 2017:277). It can be seen as both preventive and therapeutic as it provides both physical and mental benefits (Ross & Thomas, 2010:3); the "postures" are the physical positions which co-ordinate breathing with movement (Polsgrove *et al.,* 2016:27). Therefore, all major muscle groups are systematically stretched and strengthened (Ross & Thomas, 2010:3; Polsgrove *et al.,* 2016:27; Iftekher *et al.,* 2017:277). Studies have shown that yoga improves: strength (targeting under-utilized muscle groups), balance (Jeter *et al.,* 2014) (better balance and co-ordination leads to better technique and form), and flexibility (enhanced joint and muscle pliancy translates to a greater range of motion and in turn, injury prevention) (Ross & Thomas, 2010; Polsgrove *et al.,* 2016:27; Iftekher *et al.,* 2017:277). A 10-week preliminary study done on the impact of yoga on specific aspects of athletic fitness amongst soccer players revealed that the group who practiced yoga demonstrated improvement in both flexibility and balance measures (Polsgrove *et al.,* 2016:27).

Likewise, to other sports, rhythmic movement is seen as a multifaceted activity which demands on numerous elements with direct and indirect effects on the physiology and physical attributes of an individual (Angioi *et al.,* 2009:478). It is possible to propose that rhythmic movement interventions could have a positive effect on an athletic population such as rugby players.

2.5.3 Rhythmic movement interventions

Amongst other varying studies, there are two specific studies which closely resemble the rhythmic movement intervention of the current study. First, Dyke (2015:5) conducted a study, including 30 participants (17 male and 13 female) between the ages of 18 and 40 years old, which compared the dynamic balance of ballroom dancers and soccer players. 15 participants participated in ballroom dance on a regular basis (at least 3 times per week for a minimum of 30 minutes) and the other 15 participated regularly in soccer (weekly matches and training for a minimum of 30 minutes). The data suggested that both soccer players and ballroom dancers performed similarly on dynamic balance tests; this is largely because both sport codes share similar dynamic movement and balance patterns. Additionally, Dyke's study was consistent with similar previous studies showing that the soccer players have dynamic balance skills comparable to other athletes with similar skills and patterns of movement (Bhat & Moiz, 2013:222; Chander *et al.,* 2014:13; Dyke, 2015:6). The benefits from this study include: balance exercises showed to reduce the risk of lower extremity injuries by 39%, the risk of acute knee injuries by 54%, and the risk of ankle sprains by 50% (Hubscher *et al.,* 2010). It can furthermore reduce the risk of ACL injuries, especially in athletes with a history of ACL sprains (Hubscher *et al.,* 2010). For these reasons, improved balance was seen to enhance athletic performance and reduce injury risks (Hubscher *et al.,* 2010; Dyke, 2015:17).

Similarly, to Dyke (2015), another study, refers to an English community project called 'Dance Division' (Gard, 2006:63). The initiative involved attaining the support of professional soccer clubs to which specific days were allocated to train alongside elite dancers. The aim of the project was to introduce 360 000 males to the sport of dance, in the hope that the myth and discrimination associated with it, would be dismissed. Various workshops were presented to the soccer players in order for them to learn about the several benefits of dance and promotional videos were played at fixtures during the half-time break. The essential goal of the community project was to create awareness and to attract the interest amongst the male soccer players by showing them that dance could enhance their soccer skills and performance. Therefore, similarly to Dyke (2015), due to the benefits, it lead coaches (in both studies) to believe that dance training can improve balance, coordination and performance in participants of other sports too (Gard, 2006:63; Dyke, 2015:17).

Additionally to these studies, other studies implemented rhythmic movement interventions amongst non-dancers and dancers. Connolly *et al.* (2011:53) explored the health and well-being implications of a contemporary dance intervention amongst female adolescents. In the study ‘Dance 4 your life’, 55 females (aged 14) were recruited for the study with the purpose to assess the physiological and psychosocial impact of contemporary dance classes. Various pre- and post-tests were done on bio-motor skills such as upper body strength, flexibility, aerobic fitness, as well as tests on intrinsic motivation and attitudes towards dance. The intervention consisted of 5-12 hours of dance classes during a 6-week period. The results from the study indicated an increase in aerobic capacity, upper body strength and self-esteem, while no significant change was seen in flexibility. Results confirmed that dance is able to statistically improve some components of physical fitness and psychological well-being (Connolly *et al.,* 2011:59-61).

Other dance initiatives similar to Dyke (2015), was ‘Essentially Dance’ (2009) which illustrated that Ballroom and Latin American dance was popular and enjoyed by both males and females and thus, dance teachers reported a boost in the self-esteem level of individual students (Keay & Spence, 2009). ‘Dance for Health’ is another research action project which involved 6 months of research into the impact of community dance on physical health, psychosocial well-being and aspects of social inclusion (Norfield & Nordin-Bates, 2012:257). The dance classes were defined by researchers as dynamic in nature with an emphasis on strength building; core and upper body strength with moderate to advanced stretches was included into each of the sessions. The study reported positive effects on cardiovascular fitness, lung function and flexibility along with positive impacts on areas of confidence, social health and emotional well-being (Norfield & Nordin-Bates, 2012:257).

The assumption then is that rugby players, who also need to demonstrate a complexed interaction of the same bio-motor skills as dancers and soccer players, would also benefit from a rhythmic movement intervention in the same way that soccer players experienced benefits.

2.6 Training Methods

2.6.1 Background

According to Hulin and Gabbett (2015:703), the demands of rugby match-play have changed greatly over the years. The fact that match success has been attributed to the ball being in play for longer is an example of this. The study found that competitive success is associated with teams being able to maintain higher ball-in-play time following the peak time. Furthermore, rest time between cycles of play is shorter and players make considerably more passes and tackles during a match (Murray *et al.,* 2014:73). For the contemporary rugby player, conditioning programmes (including training methods) should therefore reflect on these and other facets of the game in order to meet game demands, avoid injury and acquire sufficient physiological preparation to be successful (Gabbett *et al.,* 2012:703; Murray *et al.,* 2014:74; Hulin & Gabbett, 2015:703).

It is evident that the intermittent, contact nature of rugby requires of the players to have well-developed endurance, high intensity, speed, strength and power capabilities (Argus *et al.,* 2010:680; Austin *et al.,* 2011:71; Gabbett *et al.,* 2012:489). In terms of rugby conditioning, the common belief dictates that these elements should be developed through focused, isolated training blocks (Bompa & Buzzichelli, 20018:46; Haff, 2016:404) however, in reality, competition structure dictates that these qualities be developed concurrently (Tee *et al.,* 2018). Thus, more recent reports have indicated that tactical periodisation approaches are used within elite rugby which is based on the principle that training should never be separate but rather that the physical, tactical, technical and mental elements of preparation should all be developed holistically (Delgado-Bordonau & Mendez-Villanueva, 2012:30; Tee *et al.,* 2018:685). Therefore, this integrated approach which allows for the development of various different physical and tactical abilities, may be effective for conditioning rugby players (Tee *et al.,* 2018:683).

The inclusion of other non-traditional approaches to training has become more popular within rugby conditioning. Non-traditional training approaches are those which do not necessarily include rugby-based activities. For example, while a traditional rugby periodised plan focuses primarily on the inclusion of gym and field-based training centred around rugby-related movements and activities, non-traditional approaches include other activities from different sport disciplines such as; athletics, boxing, olympic wrestling, swimming, and yoga as used by other elite rugby teams (Vaz *et al.,* 2013:229-230; Tønnessen *et al.,* 2015:31). Furthermore, the use of small-sided games are also used to break away from traditionally rugby training regimes because it calls for a level inventiveness, decision-making and creativity from the player which is not necessarily required by typical rugby-based approaches to conditioning (Foster *et al.,* 2010:910; Halouani *et al.,* 2014:3594; Bompa & Buzzichelli, 2018:110).

2.6.2 The traditional approach to rugby training

Sport specific training stems from the need to prepare players adequately for the specific demands of the sport (Johnston *et al,* 2014:1088). When considering the traditional, specific approach to rugby training, literature refers to gym and field-based activities particularly related to rugby-specific movements. Some common approaches to training with a specific focus on one or more bio-motor skills include: resistance-based training (which entails training for muscular strength and power), agility and change-of-direction speed training, plyometric training and speed and agility training (Corcoran *et al.,* 2009:67; Harrison & Bourke 2009:275; Wheeler *et al.,* 2010:445; Tobin & Delahunt *et al.,* 2014:367-368; Young *et al.,* 2015:161; Gannon *et al.,* 2016:382; Speirs *et al.,* 2016:388).

In a study by Rivière *et al.* (2017:948), two different strength training programmes were adopted in order to examine strength, velocity and power adaptations in youth rugby players. Between variable resistance training and traditional free-weight resistance training interventions, it was found that the variable resistance training, using elastic bands, may offer greater training stimulus than the traditional free-weight resistance training in terms of improving upper-body strength, velocity, and power amongst rugby players (Rivière *et al.,* 2017:948). Similarly, in a systematic review and meta-analysis, by Behm *et al.* (2017:423), on the effectiveness of traditional strength versus power training on muscle strength, power and speed with youth, one of the important conclusions was that a greater magnitude improvement in power measures were seen; this directly corresponds with the training specificity principle (Bhem *et al.,* 2017:423). In other words, the training specificity has a direct determining effect on the magnitude of training adaptations when the training mode, velocity and other characteristics most closely match the subsequent activity, sport or tests (Bhem *et al.,* 201:4237). Chaouachi *et al.* (2014:1483) reported similar findings in a study which compared two types of power training (Olympic weightlifting and plyometric training) and traditional resistance training. The study's results showed that, in agreement with the specificity principle, Olympic weight lifting and plyometric training (Argus *et al.,* 2012:2698) provided a greater level of improvement in the counter movement jump in comparison to traditional resistance training (Chaouachi *et al.,* 2014:1483).

Last but not least, concurrent speed and resistance training (Suarez-Arrones *et al.,* 2014:667) and concurrent strength and endurance training (Baker *et al.,* 2011:3-4; Jones *et al.,* 2016:2399) also form part of the list of traditional approaches to rugby training. Concurrent speed and resistance training has been shown to lead to an improvement of greater magnitude in both repeated-sprint performance and muscle power output (Suarez-Arrone *et al.,* 2014:667). From the afore-mentioned examples, it is evident that strength and conditioning coaches and trainers tend to work on each bio-motor skill in isolation as it relates to rugby-specific movements and skills.

2.6.3 Non-traditional approaches to rugby training

In terms of non-traditional strength and conditioning training as means for improving specific performance variables, the available literature refers to athletes from various sport disciplines, who make use of other non-traditional (i.e., training unrelated to their sporting code) training approaches. More recently, the inclusion of other non-rugby related activities and cross-training have become more popular within the rugby-training environment and it sees teams drawing from other sports as means of training such as athletics (for speed training techniques), volley ball, handball, soccer and basketball (all of these are used for high intensity movements, passing, speed and fitness as well as plyometric training) (Vaz *et al.,* 2013:226). These other forms of training allow the players to engage in other, more innovative means of training and conditioning and to develop creative thinking

Incorporating cross-training into training programs is a technique which is used amongst many sports to increase the physical and technical development, improve training discipline, allow a break from the training routine, reduce the risk of overuse injury and also maintain a training stimulus during an injury rehabilitation process (Vaz *et al.,* 2013:225; Tønnessen *et al.,* 2015:29). The familiar example within the field of rugby includes “small-sided games” used in training as a means of improving the skills and physical fitness levels of team rugby players and it also allows simulation of movement patterns of the particular team sport (Gabbett & Jenkins, 2010[b]:204~~)~~. Small-sided games in rugby allow players to execute rugby skills under fatigue circumstances and were shown to improve athletic performance of elite rugby players following an 8-week small-sided game intervention (Gabbett & Jenkins, 2010[b]:204; Foster *et al.,* 2010:906;Seitz *et al.,* 2014:971; Weaving *et al.,* 2014:905). Additionally, in a study by Winwood *et al.* (2015:429), the effects of strongman versus a traditional training programme on a variety of body composition, muscular function, and performance measures were examined. The study was used as a means to compare two different forms of strength training, amongst rugby players, whose essential goal was to improve their bio-motor skills (strength, power, speed, and change-of-direction) (Winwood *et al.,* 2015:429). Although neither of the two types of training showed a significant advantage over the other, the strongman training program still showed evidence of great potential benefits for rugby players in terms of improvements in initial acceleration; this is an important training effect for rugby players needing to break through tackles and gain possession during match situations (Winwood *et al.,* 2015:429).

The non-traditional approach to training for a particular sport, widely popular amongst endurance athletes, allows athletes to incorporate other bio-motor skills such as strength and endurance training concurrently with their original training programs (Bompa & Buzzichelli, 2015:99-101). Regarding rugby, English and South African teams have made use of visual skills coaches in order to improve their visual- and proprioceptive skills and also consider strength, speed, anaerobic power, aerobic capacity and technical skills as cross-training programmes (Vaz *et al.,* 2013:225). Other examples of possible cross-training activities for rugby teams include (but are not exhausted to): sprinting (for speed training techniques), volley ball, handball, soccer, basketball (all of these are used for high intensity movements, passing, speed and fitness as well as plyometric training), Olympic wrestling games (which are used by the New Zealand All Blacks, South African Springboks, England and French rugby teams to simulate and train attacking and defence drills) as well as swimming (whole body fitness) and yoga (strength and flexibility training) (Vaz *et al.,* 2013:225).

Therefore, many of the fitness elements need to be trained concurrently because of the demanding competitive calendar. Due to the physical demands being related to the activities of the positional role of the player, a tactical approach has been adopted more recently, which sees the integration and manipulation of different bio-motor skills throughout the season. Rhythmic movement is seen as a multifaceted activity which demands on numerous conditioning essentials with direct and indirect effects on the physiology and physical attributes of dancers (Angioi *et al.,* 2009:475). The benefits of rhythmic movement as a non-traditional approach to training, has further been explored in literature as a potential means for training bio-motor skills and improving performance. Thus, similarly to the integrated tactical approach, rhythmic movement allows for training many bio-motor skills concurrently. Arguments in support of including non-traditional (non-rugby based) approaches to training include strengthening weak links, injury prevention and means of avoiding training monotony (Tønnessen *et al.,* 2015:29). However, and despite the importance seen and given to non-rugby based approaches to training within the sport of rugby and amongst rugby clubs nowadays, recent scientific research related to this, is limited (Vaz *et al.,* 2013:418).

2.7 Summary

Evidence from research suggests that rugby has become faster and more physically demanding due to the change in trends of match play as well as players' physical characteristics (Lombard *et al.,* 2015:980; Vaz *et al.,* 2016:15; Read *et al.,* 2017:645; Jones *et al.,* 2018:2399). Therefore, the intermittent, contact nature of rugby requires of the players to have well-developed bio-motor skills such as endurance, flexibility, balance, speed, strength and power (Argus *et al.,* 2010:679; Austin *et al.,* 2011:259; Gabbett *et al.,* 2012:487). The assumption is that because rugby players also need to demonstrate a complexed interaction of the same bio-motor skills as dancers, soccer players and other athletes, they too would benefit from a rhythmic movement intervention (Gard, 2006:63; Conolly *et al.,* 2011; Nortfield & Bates, 2012:257; Dyke, 2015:35). It is possible to propose that a rhythmic movement intervention, as a non-traditional approach to rugby training, could have a positive effect on rugby players.

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CHAPTER 3

METHODOLOGY

This chapter is included herewith in accordance with the referencing style of the Department Sport Science, Stellenbosch University.

3.1	**INTRODUCTION**	**69**
3.2	**STUDY DESIGN**	**69**
3.3	**PARTICIPANTS**	**69**
3.4	**EXCLUSION AND INCLUSION CRITERIA**	**70**
3.5	**DATA COLLECTION PROCEDURE**	**70**
3.6	**PRE- AND POST-TESTING PROTOCOL**	**71**
3.7	**INTERVENTION**	**74**
3.8	**STATISTICAL ANALYSIS**	**76**
3.9	**ETHICAL CLEARANCE**	**77**
3.10	**DATA STORAGE**	**77**
3.11	**DISSEMINATION OF MATERIAL**	**77**
3.12	**IMPLEMENTATION OF FINDINGS**	**78**
3.13	**REFERENCES**	**79**

3.1 INTRODUCTION

Training for rugby has primarily comprised traditional, rugby-based and specific approaches to training, such as resistance-based training, agility and change-of-direction speed training, plyometric, speed and agility training and small-sided games to name a few (Harrison & Bourke, 2009:275; Wheeler *et al*., 2010:445; Kennett *et al*., 2012:2037; Tobin *et al*., 2014:370; Young *et al*.,2015:243; Gannon *et al*., 2016:381; Speirs *et al*., 2016:388). These approaches centre on the belief that it should develop all rugby fitness elements through focused, isolated training blocks (Haff, 2016; Bompa & Buzzichelli, 2018:93). Competition structures, however, dictates that these qualities should be developed concurrently (Tee *et al*., 2018:2-4). It has led to coaches applying tactical periodization within rugby, which is based on the principle that training should never be separate, but that the physical, tactical, technical and mental elements of preparation should all be developed holistically (not in Ref list. & Mendez-Villanueva, 2012:28; Tee *et al*., 2018:2-4). An example of a training approach that incorporates multiple fitness elements concurrently is rhythmic movement.

Rhythmic movement involves the execution of different motor skills, integration and sequencing of actions between limbs, timing and spatial precision (Gard, 2006:63; *et al*.,2010:77; Alpert, 2011:155; Dyke, 2015:35). Interventions based on rhythmic movement, have been explored in literature (amongst both athletic and non-athletic populations), and a range of benefits related to bio-motor skills were found (Dyke, 2015:30). The assumption is that an athletic population, such as rugby players, who also need to demonstrate a complexed interaction of the same bio-motor skills as dancers and soccer players, would also benefit from a rhythmic movement intervention.

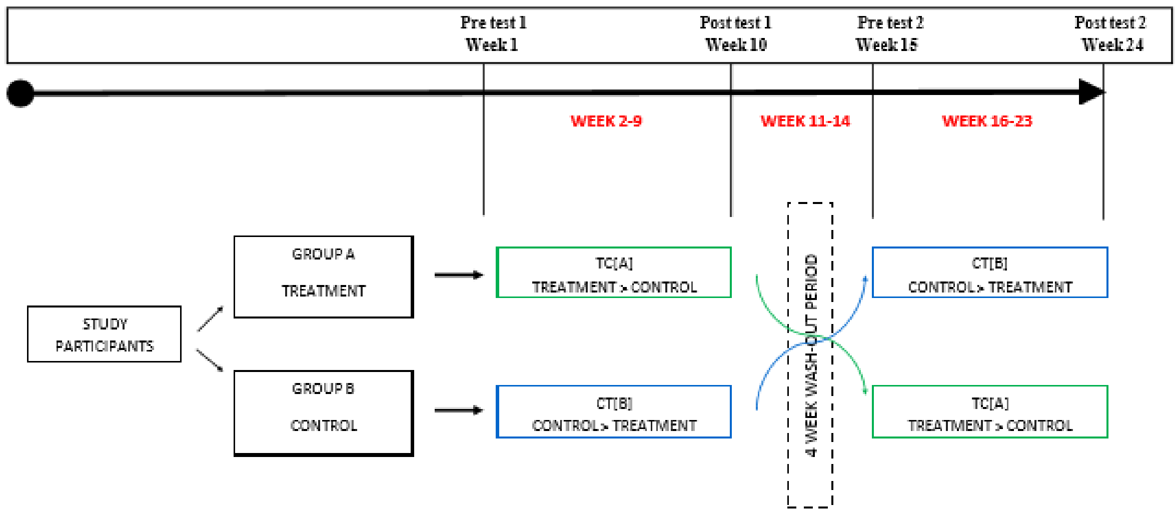
3.2 STUDY DESIGN

The study design for this study is classified as a crossover experimental design (Calmeyer *et al*., 2011:148). A crossover trial involves two treatments, which are consecutively administered in each participant recruited in the study (Dwan *et al*., 2019:1-2). The main purpose served by this study design is to provide a basis for separating treatment-effects from period-effects and to establish whether the intended outcome(s) of the intervention have materialised (Dwan *et al*., 2019:2). The separation is achieved by calculating the treatment-effects separately in two sequence groups produced via randomisation (Dwan *et al*., 2019:2). In this design, pre-post changes in the experimental group may be directly compared to changes in the control group to note the effects of the intervention (Senn, 1995:171). Crossover trials require a washout period to ensure that baseline data are comparable. The reversibility of a treatment effect is a prerequisite for applying a crossover design and determines the length of the washout period (Hecksteden *et al*., 2013:1-2).

Particularly in training studies, the washout period is challenging, yet important as the effects of training need considerable time to diminish (Hecksteden *et al*., 2013:1-2). Advantages of a study design such as this include: ability to assign and administer the intervention in a precise, controlled way gets rid of selection bias, and facilitates blinding of the identity of treatments from investigators, participants and assessors. Disadvantages include, high cost, time consuming and results which may not always mimic real life treatment situation (Dwan *et al.,* 2019:2).

Figure 3.1: **CROSS-OVER EXPERIMENTAL STUDY DESIGN**

(Adapted from: Li *et al.*, 2015)



As depicted in Figure 3.1*,* the effect of a 16-week rhythmic movement intervention on selected bio-motor skills of Western Province Academy rugby players was tested. During the first week, the participants attended an information session and signed the informed consent. Following the information session the participants were divided into a treatment-control and control-treatment group. During week 1, both groups underwent pre-test 1. From weeks 2-9, the treatment-control (TC^A) group was exposed to the rhythmic movement intervention while the control-treatment (CT^B) group continued their normal rugby training. In week 10 both groups completed the post-test 2 and from week 11 – 14 underwent a 4-week washout period (Faude et al., 2014; Hecksteden et al. 2018). Following the washout period, both groups participated in pre-test 2 in week 15. Thereafter CT^B group participated in the rhythmic movement intervention, while the TC^A group continued their normal rugby training from and including weeks 16-23. Post-testing 2 followed for both groups in week 24 of the intervention. The content of the intervention was exactly the same for both groups.

3.3 PARTICIPANTS

Academy rugby players (N=54) from the Western Province Rugby Union, South Africa, (age 18±0.81years, height 1.76±0.69cm and weight 76.77±10.69kg), participated in the current study. The intervention procedures were explained and players were informed of the benefits and risks associated with this study before providing written informed consent and participating in the study. Before commencement of the study, the players were familiarised with tests and testing protocol. Only players free of injury before the start of pre-test[1] were included in the study. The participants were randomly divided into a treatment-control TC[A] (n=28) and control-treatment CT[B] (n=26) group by an independent third party. Ethical approval (Ethics Project number: 7111), was obtained from the Research Ethics Committee: Human Research of Stellenbosch University.

3.4 EXCLUSION AND INCLUSION CRITERIA

Table 3.1: **INCLUSION AND EXCLUSION CRITERIA**

Participants were included if they:	Participants were excluded if they:
• Played rugby at an amateur level. • Were part of the men's rugby academy in Western Province Rugby Union. • Signed the informed consent form. • Were ≥ 18 years old. • Attended the pre-tests. • Attended the post-tests. • Attended at least 12 of the 16 (75%) consecutive rhythmic movement sessions.	• Were not enrolled at an academy in Western Province. • Were injured at any point during the intervention (refers to all injuries including concussions diagnosed by a medical professional).

3.5 DATA COLLECTION PROCEDURE

During the pre- and post-tests, all the participants were tested on various fitness elements in a particular order. The testing protocols were categorised broadly under flexibility (sit-and-reach test), dynamic balance (star excursion balance test), agility (Illinois agility test with the ball[1] and without the ball[2]), power (vertical jump test[1] and seated medicine ball throw test[2]) and local muscular endurance (1 minute push-up[1], 2 minute crunch[2], pull-up test[3] to failure and single leg squat[4] to failure). The rhythmic movement programme was conducted and choreographed by the primary researcher who is a professional dancer and choreographer. In order to compile the intervention, the primary researcher looked at the most common movement patterns (such as side-stepping, vertical jumps and various lateral movements during play) and exercises of rugby players by watching match footage. The intervention consisted of 32, 60-minute sessions, over a period of 16 weeks (2 x 8 weeks). These sessions were part of their weekly planning and not an extra session. Each session started with a 10-minute progressive aerobic endurance rhythmic movement routine as a warm-up, followed by 45 minutes of learning new rhythmic exercises and repeating it to music and ended with a 15-minute cool-down involving progressive stretching.

3.6 PRE- AND POST-TEST PROTOCOL

To test the participants' bio-motor skills they were put through specific tests on their specific test day. As depicted in Table 3.2 below, during the pre- and post-tests, all the participants were tested on various fitness elements in a particular order. These tests were categorised broadly under flexibility (sit-and-reach test), dynamic balance (star excursion balance test in 8 different directions), agility[1 & 2] (Illinois agility test without a ball and with a ball, respectively), power[1 & 2] (seated medicine ball throw test and vertical jump test, respectively) and local muscular endurance[1-4] (1-minute push-up, 2-minute crunch, pull-up test to failure and single leg squat to failure, respectively).

Table 3.2: **DESCRIPTION OF TEST USED IN THE STUDY**

Bio-motor Skill	**Test name**	**Purpose**	**Validity & reliability**	**Equipment**
Flexibility	Sit-and-reach test	The test was used to measure the flexibility of the hamstrings and lower back.	Overall results for the sit-and reach tests have a moderate mean criterion-related validity for estimating hamstring extensibility (rp = 0.46 - 0.67) (Mayorga-Vega *et al*., 2014:1). The findings showed acceptable reliability measures for SRT proved to be "good" (0.92 ICC) (Ayala *et al*., 2012:220).	Sit-and-reach box.
Balance	The Star excursion balance test (SEBT)	To test and measure the dynamic balance of the participant. Participants reached in 8 different directions with one foot first, before changing feet and doing so on the other side.	Reliability for the SEBT was rated as "high" (ICC = 0.84 > 0.92) test re-test values and high validity scores with Pearson r > 0.96 (Kanko *et al*., 2019:581; Coughlan *et al*., 2012:366).	Measuring tape and markers.
Agility	The Illinois agility test	The Illinois agility test, with-and without the ball in hand, was used to test the participants' agility and ability to change direction of their body rapidly whilst moving. Additionally, it involves utilizing	The relative and absolute reliability of this test is identified as "high" (> 0.91 ICC) (Negra *et al*., 2017:727). Thus, the test has a good ability to detect real changes in the ability to change direction in male team sport athletes and, thus, is considered a valid test for agility (Hachana *et al*., 2013:2752).	Cones (9), speed cells, tape measure.

		strength, speed, balance and coordination.		
Power	Vertical jump test	The vertical jump test is used to measure lower body (leg) power.	The vertical jump test has been shown to be a valid and reliable measure of lower-body explosive power - results indicated "high" ICC (0.969-0.0995) and low coefficients of variation (1.54 - 4.82%) (Rodriguez-Rosell *et al*., 2017:196-206).	A smooth wall, chalk and a measuring stick.
	Seated medicine ball throw test.	The aim of the seated medicine ball throw is to measure upper body power.	Validity (Pearson product-Moment correlation) for the SMBT was r = 0.641 (1.5kg) and r = 0.614 (3kg). Therefore, SMBT appears to be a highly reliable test for upper body power (Harris *et al*., 2011:2346). Reliability for the seated medicine ball test was 0.994 (1.5kg) and 0.989 (3kg).	Medicine ball (3kg) and a tape measure.
Endurance	Push-up test (1-minute)	The aim of the push-up test is to measure the subject's upper body strength and endurance.	Validity of the test resulted in r = 0.99 (high validity). Reliability of the test (ICC) resulted in r = 0.93 (male) and r = 0.93 for females. The use of the push-up test shows a higher validity in males versus females in terms of testing muscular strength and endurance of the upper body (Hashim & Madon, 2012:1028).	Stopwatch and a gymnastics mat.

	Crunch test (2-minutes)	The Crunch test measures a subject's core muscle strength and endurance.	The crunch or partial sit-up test is considered both valid and reliable with a very high test re-test reliability value (r = 0.98) (Miller, 2012).	Stopwatch and a gymnastics mat.
	Pull-up test (to failure)	The pull-up test (to failure), also known as a chin-up test, is used to measure upper body muscle strength and endurance.	High ICC values (>0.83) have been reported for the pull-up test for its reliability; there is no published data assessing the reliability of the test for adults (Burnstein *et al*., 2011; Miller, 2012). Both the traditional and modified version of the test are a reliable and valid method for assessing muscular endurance (Miller, 2012).	Pull-up bar.
	Single-leg to box squat	The squat is used to measure lower body endurance. Similarly to a standard two-legged squat, the test is performed by lowering to a box, on a single leg.	There is no published validity or reliability data for the single-leg to box squat for assessing lower body endurance (Miller, 2012).	A Chair / bench.

3.7 INTERVENTION

In order to design the rhythmic movement contents for each session, the researcher had to take into account that the rhythmic movements would need to mimic the movements most familiar to the players. Thus, the intervention was designed specifically for rugby players who are usually involved in high intensity training programmes, which simultaneously include various movement patterns. After consultation with the primary supervisor who has a background in dancing, the movements were adapted from various dance genres including freestyle dancing, contemporary and ballet. Furthermore, the choreography and sessions were planned in such a way as to target the specific bio-motor skills that would be tested. The warm up targeted aerobic activity, followed by the body of the sessions, which consisted of rhythmic movements aimed at improving agility, dynamic balance, power and local muscular endurance. The cool down specifically aimed at enhancing flexibility.

The intervention comprised 32, 60-minute sessions over 16 weeks. These sessions were part of their weekly planning and not an extra session. Each session started with a 10 minute, progressive aerobic endurance rhythmic movement routine as a warm-up, followed by 45 minutes of learning new rhythmic movement exercises and repeating it to music and ended with a 15 minute cool-down involving progressive stretching. While the experimental group was exposed to the intervention, the control group continued their normal rugby-training program.

The rhythmic movements were comprised of a rhythm of 8 beats and music from the various genres of dance. The purpose of the first 2 to 9 weeks (Appendix C) was to expose the participants to various movements that targeted the lower body. The movements were ballet orientated and required lower body endurance, power, strength and flexibility. The sessions were all made up of the same rhythmic movements with progressions (either in speed or repetitions) for weeks 2 to 9. The music was between 90 to 100 beats per minute (bpm). After the first 8 weeks, a 4-week washout period was implemented in order to avoid a "carry over" effect of the rhythmic movement intervention and not having the intervention.

For the next 8 weeks, the control group was exposed to the intervention, while the experimental group continued normal rugby training. The rhythmic movements were based on endurance, power, strength and flexibility bio-motor variables. The sessions were all made up of the same rhythmic movements with progressions (in either speed or repetitions) for weeks 16 to 23. The music was between 90 to 130 BPM.

3.8 STATISTICAL ANALYSIS

Statistician Prof Marin Kidd from the Centre for Statistical Consultation, Stellenbosch University, assisted with the statistical analysis. The Statistica Data Processing package (Statsoft Inc., 2016) was used to process the data. Descriptive statistics were reported as means and standard deviations. A series of one-way ANOVAs with post hoc LSD t-tests were used to examine between-group (TC^A versus CT^B group) differences. Results were considered statistically significant if $p \leq 0.05$.

3.9 ETHICAL CLEARANCE

The protocol of this study was submitted to the Departmental Ethics Screening Committee (DESC) of the Department of Sport Science and the Research Ethics Committee at Stellenbosch University (REC); ethics Project number 7111 (Appendix D: Ethical Clearance Letter). The study was considered low risk. Data was stored on a password-protected computer and on a protected file within the programmes used to store the data. Hard copies of informed consent and data were stored in a locked storeroom with an alarm system and with limited access at the Department of Sport Science, Stellenbosch University. Only the primary researcher and the two supervisors had access to the data. The statistician, who assisted with data analysis, only worked with an anonymous coding system. Data will be kept for six years where after it will be destroyed. The goal was to publish one article in which the field-testing data will be discussed and compared. Only data concerning field tests and bio-motor skills were reported on and no player or team was identifiable. Participants had the choice to withdraw from the research study, without penalty.

3.10 DATA STORAGE

The data was stored on the primary researcher's password protected laptop. It was backed up on a password protected external hard drive, which was kept safe in the Departments of Sport Science's safe, Stellenbosch University.

3.11 DISSEMINATIN OF MATERIAL

The results of the current study will be published in a journal that requires the underlying data to accompany the article. The data supporting the publication will be deposited in an accredited Open Access repository (Digital Object Identifier). Research findings will be presented at national and international conferences, as well as to community and public platforms.

3.12 IMPLEMENTATION OF FINDINGS

Upon completion of the intervention, the bio-motor skills were analysed, which showed statistically significant improvements after treatment was implemented. This indicated the bio-motor skills that had a true treatment effect over the 16 weeks, and therefore, has the potential to produce similar results in the future. Furthermore, careful note should be taken of those bio-motor skills, which showed a slight improvement during the time of no-treatment in order to establish whether it was because of a learning effect (of the tests performed), or other factors (the rugby conditioning programme) that produced improvement. The skills that did not improve, while treatment was implemented should also be identified. In this way it will be possible to establish which bio-motor skills improved because of the treatment only, which bio-motor skills need different rhythmic movements in order to more closely reflect rugby specific movements and which bio-motor skills need more stimulus from the intervention. Lastly, a re-design of the rhythmic movements should be performed according to rugby specific bio-motor skills and rugby movements. In other words, the principle of training specificity (in terms of rugby-related and orientated rhythmic movements), should be one of the important factors to incorporate in order to achieve the desired effects of the intervention. There should be consultation with the participants and rugby experts (coaches and trainers) in terms of what types of rugby movements more closely resembles the specific bio-motor skills and should form part of the rhythmic movement programme. The time needed in order for these rugby specific bio-motor skills to improve should also be taken into account.

Apart from those bio-motor skills, which showed a statistically significant improvement, all the bio-motor skills showed improvement at some point during the intervention. Thus, based on the findings of the study, the researcher would recommend that coaches (including specialist coaches, such as strength and conditioning, as well as fitness coaches), use rhythmic movement in their training programmes to improve all the bio-motor skills (flexibility, agility, dynamic balance, power and local muscular endurance). Until more extensive research is done to reveal significant results on all the bio-motor skills, the researcher suggests the use of rhythmic movement alongside the rugby conditioning programme to improve selected rugby specific bio-motor skills for the Western Province Academy rugby players.

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CHAPTER 4

RESEARCH ARTICLE

THE EFFECT OF A RHYTHMIC MOVEMENT INTERVENTION ON SELECTED BIO-MOTOR SKILLS OF WESTERN PROVINCE RUGBY UNION ACADEMY PLAYERS

This article will be submitted for publication in the Journal of Sports Sciences (Appendix E). The article is included herewith in accordance with the guidelines for authors of this esteemed journal. However, to provide an orderly and well-formed final product for this thesis, the article has been edited to represent an actual published article, as it would appear in this particular journal. This does not imply that the article has been accepted or will be accepted for publication. Consequently, the referencing style used in this chapter may differ from that used in the other chapters of this thesis.

TITLE PAGE		**84**
Abstract		**85**
ABSTRACT		**85**
4.1	**INTRODUCTION**	**85**
4.2	**METHODS AND MATERIALS**	**87**
4.2.1	Study Design	87
4.2.2	Participants	87
4.2.3	Procedures	88
4.3	**STATISTICAL ANALYSIS**	**89**
4.4	**RESULTS**	**89**
4.5	**DISCUSSION**	**97**
4.5.1	Practical Application	99
4.6	**CONCLUSIONS**	**99**
4.7	**ACKNOWLEDGEMENT**	**100**
4.8	**DISCLOSURE OF INTEREST**	**101**
4.8.1	Disclosure of interest	101
4.9	**REFFERENCES**	**101**

Title page

Title: The effect of a rhythmic movement intervention on selected bio-motor skills of Western Province Rugby Union academy players

Field of study: Sport Science

Running title: Rhythmic movement for rugby players

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The effect of a rhythmic movement intervention on selected bio-motor skills of Western Province Rugby Union academy players

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ABSTRACT

Rhythmic movement is seen as a multifaceted activity, which demands a large number of conditioning essentials with direct and indirect effects on the physiological and physical attributes of dancers. The primary aim of this study was to investigate the effect of a 16-week rhythmic movement intervention on selected bio-motor skills in academy rugby players. Rugby players (N=54) (age 18.66±0.81 years; height 1.76±0.69cm; weight 76.77±10.69kg), from the Western Province Rugby Union Academy were randomly divided into a treatment-control [TC^A] (n=28) and a control-treatment [CT^B] (n=26) group. In this crossover experimental design, the interaction effect of the treatment order and the treatment time overall between the CT^B and TC^A group was determined. Results revealed a statistically significant difference (p=≤0.05) between power[1&2] as well as local muscular endurance[2, 3 & 4]. These specific bio-motor skills showed a significant improvement during the time the treatment was implemented. When comparing backs and forwards, statistically significant improvements were noted specifically in agility[1] and power[1] from pre- to post treatment (p=≤0.05)

KEYWORDS: Rhythmic movement, rugby, academy players, bio-motor skills.

4.1 Introduction

Evidence from research suggests that rugby has become faster and more physically demanding because of changes in trends of match play, as well as players' physical characteristics (Lombard *et al.,* 2015; Owen *et al.,* 2015; Jones *et al.,* 2018; Read *et al.,* 2018). The intermittent, contact nature of rugby requires of the players to have well-developed bio-motor skills, such as endurance, flexibility, balance, speed, strength and power (Argus *et al.,* 2010; Austin *et al.,* 2011; Gabbett *et al.,* 2012). Therefore, rugby encompasses various forms of fitness elements, which need to be trained both on and off the field throughout the rugby season because of the demanding competitive calendar. For these reasons, rugby coaches and specialist coaches need to frequently adapt their training methods and programmes to accommodate and take advantage of these changes to the profile of the game in order to gain a competitive edge over opposing teams (Austin *et al.,* 2011; Hartwig *et al.,* 2011; Handcock & Cassidy, 2014; Jones *et al.,* 2018).

The inclusion of other non-traditional approaches to training has become more popular within rugby conditioning. Rhythmic movement, also referred to as "dance", involves the execution of different motor skills, integration and sequencing of actions between limbs, timing and spatial precision (Bertollo *et al.,* 2010). It requires performing movement tasks to auditory rhythmic patterns and as a multifaceted activity; thus, dependent on a large number of elements with direct and indirect effects on the physiology and physical attributes of an individual (Angioi *et al.,* 2009; Bertollo *et al.,* 2010). In terms of rugby conditioning, the common belief dictates that these fitness elements should be developed through focused, isolated training blocks (Bompa & Buzzichelli, 2018; Haff, 2016). However, in reality competition structures dictate that these qualities should be developed concurrently (Tee *et al.,* 2018). Therefore, because rhythmic movements require from an athlete to demonstrate a proficient level of muscle co-ordination, muscle stamina and strength and aerobic endurance, this makes it a good non-rugby based alternative to train bio-motor skills (Koutedakis *et al.,* 2009; Mistiaen *et al.,* 2012).

The notion of the benefits of dance as an intervention has further been explored in literature (Alpert *et al.,* 2011 Malkogeorgos *et al.,* 2011; Kiepe *et al.,* 2012; Murrock & Graor, 2014; Sharp & Hewitt, 2014). The specific and familiar example of Yoga has been used amongst many international football, rugby, cricket and golf clubs in countries such as South Africa (SA) (Iftekher *et al.,* 2017). Yoga is a highly structured activity that can simultaneously enhance several specific components of fitness. Furthermore, it mimics critical aspects of athletic performance, such as balance, flexibility, muscular strength, muscular endurance and co-ordination (Iftekher *et al.,* 2017). A 10-week preliminary study on the impact of yoga on specific aspects of athletic fitness amongst soccer players indicated that the group who practised yoga, demonstrated improvement in both flexibility and balance measures (Polsgrove *et al.,* 2016).

All rugby players essentially perform some type of rhythmic movement in practise or match-play; from the duo performed between the lifters and jumpers in the line-out, the scrummaging formations to strategically timed tackles and critical displays of agility and speed to get to the try line (Gabbett *et al.,* 2012). The assumption is that rugby players, who also need to demonstrate a complexed interaction of the same bio-motor skills as dancers and soccer players, would benefit from a rhythmic movement intervention in the same way that soccer players experienced benefits. However, and despite the importance seen and given to non-rugby-based approaches to training within the sport of rugby and amongst rugby clubs nowadays, recent scientific research related to this is limited (Vaz *et al.,* 2013). The primary aim of this study was to investigate the effect of a rhythmic movement intervention on selected bio-motor skills of academy rugby players in the

Western Province Rugby Union. The first objective of the study was to investigate the effect of a 16-week rhythmic movement intervention on flexibility, dynamic balance, agility, power and local muscular endurance. Secondly, to compare selected bio-motor skills of backs and forwards after participating in a 16-week rhythmic movement intervention.

4.2 Methods and materials

Study design

The current study was based on a crossover experimental design (Mouton, 2001). A crossover trial involves two treatments, which are administered consecutively to each participant recruited for the study (Dwan *et al.,* 2019). The main purpose served by this study design was to provide a basis for separating treatment-effects from period-effects and to establish whether the intended outcome(s) of the intervention materialised (Clarke & Dawson, 1999; Dwan *et al.,* 2019). This separation was achieved by calculating the treatment-effects separately in two sequence groups, produced via randomisation (Dwan *et al.,* 2019). In this design, pre-post changes in the experimental group were directly compared to changes in the control group to indicate the effects of the intervention (Senn, 1995). Crossover trials require a washout period to ensure that baseline data are comparable. The reversibility of a treatment effect is a prerequisite for applying a crossover design and determines the length of the washout period (Hecksteden *et al.,* 2018). Particularly in training studies, the washout period is challenging, yet important; because the effects of training needs considerable time to diminish (Hecksteden *et al.,* 2018). Advantages of a study design such as this include: ability to assign and administer the intervention in a precise, controlled way gets rid of selection bias, and facilitates blinding of the identity of treatments from investigators, participants and assessors. Disadvantages include, high cost, time consuming and results which may not always mimic real-life treatment situation (Dwan *et al.,* 2019:2).

Participants

Academy rugby players (N=54) from the Western Province Rugby Union (WPRU), South Africa (age 18±0.81years; height 1.76±0.69cm; weight 76.77±10.69kg), were selected to participate in this study (Table 4.1). The intervention procedures were explained to the players and informed regarding the benefits and risks associated with the study before providing written informed consent to participate. Before commencement of the study the players were familiarised with the testing protocol. Only players free of injury before the start of pre-test 1, were included in the study. The participants were randomly divided into a treatment-control TCA (n=28) and control-treatment CTB (n=26) group by an independent third party. Ethical approval (Ethics Project number: 7111) was obtained from the Research Ethics Committee: Human Research at

Stellenbosch University and Insurance was granted for this project (Insurance Policy number: 73112118A001).

Table 4.1. Participant characteristics.

Positional groups	Age (years)	Height (cm)	Weight (kg)
Forwards (n=21)	18±1.72	1.78±0.94	79.5±14.6
Backs (n=33)	18±0.20	1.57±4.24	71±10.6
Combined (N=54)	18±0.81	1.76±0.69	76.77±10.69

Procedures

Figure 4.1 presents the framework of the study. During the first week, the participants attended an information session and signed the informed consent. Following the information session, the participants were divided into a treatment-control and control-treatment group. During week 1, both groups underwent pre-test 1. From weeks 2 to 9, the treatment-control (TC^A) group was exposed to the rhythmic movement intervention, while the control-treatment (CT^B) group continued their normal rugby training. In week 10 both groups completed post-test 2 and from week 11 to 14 they underwent a 4-week washout period (Faude *et al.,* 2014; Hecksteden *et al.,* 2018). Following the washout period, both groups participated in pre-test 2 in week 15. Thereafter the control-treatment group participated in the rhythmic movement intervention, while the treatment-control group continued their normal rugby training from- and including weeks 16 to 23. Post-test 2 followed for both groups in week 24 of the intervention. The content of the intervention was the same for both groups.

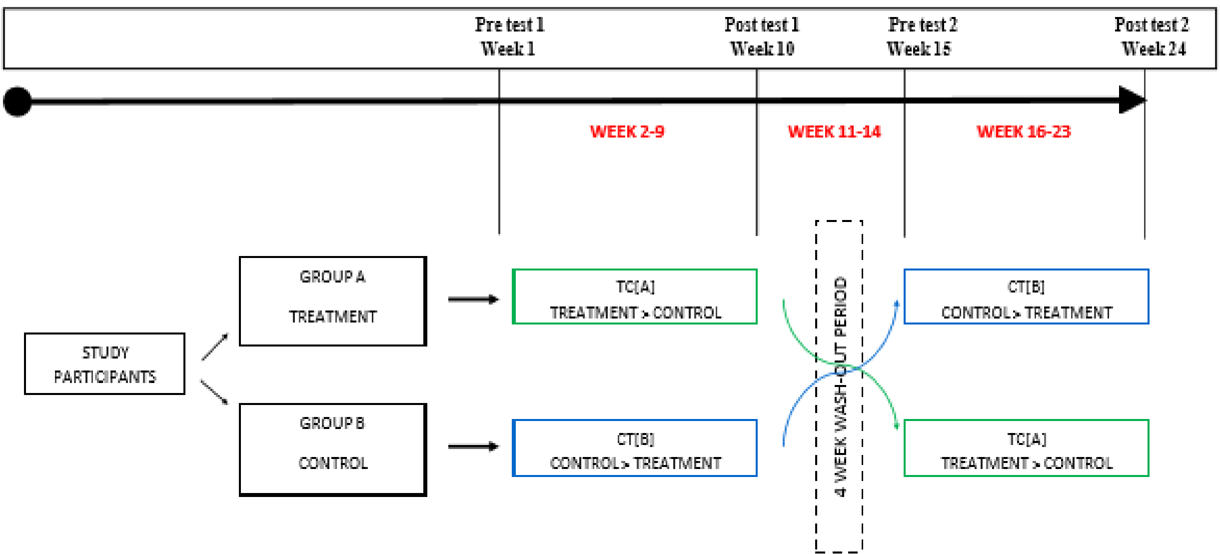


Figure 4.1. Timeline for the study.

During the pre- and post-test all the participants were tested on various fitness elements in a particular order. This testing protocol was categorised broadly under flexibility (sit- and-reach test), dynamic balance (star excursion balance test), agility (Illinois agility test with a ball[1] and without a ball[2]), power (vertical jump test[1] and seated medicine ball throw test[2]) and local muscular endurance (1-minute push-up[1], 2-minute crunch[2], pull-up test[3] to failure and single leg squat[4] to failure). The rhythmic movement programme was conducted and choreographed by the primary researcher who is a professional dancer and choreographer. In order to compile the intervention, the primary researcher looked at the most common movement patterns and exercises of rugby players by studying match footage. The intervention consisted of 32, 60-minute sessions over a period of 16 weeks (2 x 8 weeks). These sessions were part of their weekly planning and not an extra session. Each session started with a 10-minute progressive aerobic endurance rhythmic movement routine as a warm-up. The warm-up was followed by 45 minutes of learning new rhythmic movement exercises and repeating it to music, which ended with a 15-minute cool-down involving progressive stretching.

4.3 Statistical analysis

Prof Martin Kidd of the Centre for Statistical Consultation, Stellenbosch University, assisted with the statistical analysis. The Statistica Data Processing package (Statsoft Inc., 2016) was used to process the data. Descriptive statistics are reported as means and standard deviations. A series of one-way ANOVA with post hoc LSD t-tests were used to examine between-group (TC^{A} versus CT^{B} group) differences. Results were considered statistically significant if $p \leq 0.05$. Superscripts are used to indicate statistically significant differences ($p \leq 0.05$). Where superscripts, in terms of number and letters, are different, it indicates the degree of difference between means. I.e., If 4.71 ± 1.26a and 4.60 ± 1.07abc are compared, this indicates a statistically significant difference ($p = \leq 0.05$). The more superscripts used and the more variation there is between the letters, the more significantly different the results.

4.4 Results

The results of the current study will be presented as follows: the bio-motor skills (dynamic balance will be discussed separately because of the sub-variables), which revealed a statistically significant difference ($p = \leq 0.05$) when comparing pre- and post-control (no treatment). The pre- and post-treatment will be presented separately. This will be followed by the bio-motor skills that did not show statistical significance ($p > 0.05$). When comparing forwards and backs, the bio-motor skills indicating significant differences between the pre- and post-control (no treatment) and pre- and post-treatment will be presented. Lastly, the skills that did not reveal a statistical significant difference will be discussed.

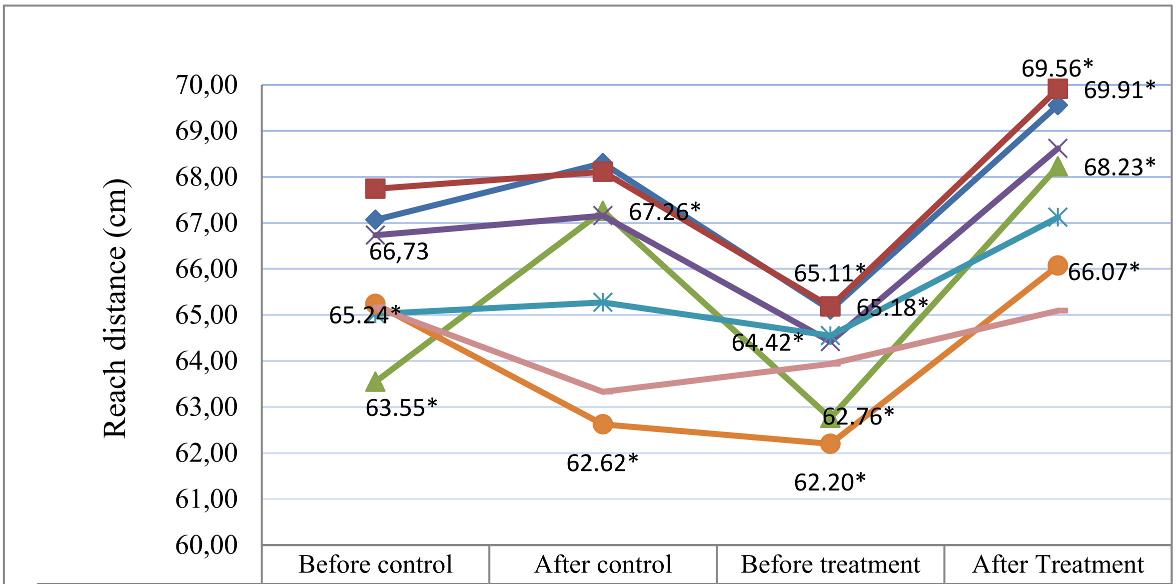
Table 4.2 presents the bio-motor skills, which indicated statistically significant differences across the treatment times. As can be seen in Table 4.2, power[1] revealed a statistically significant difference for the CT group between pre-control and pre-treatment. When comparing the TC group a statistical difference was revealed for pre-control and pre-treatment. No significant difference was noted between post-control and post-treatment. Furthermore, Table 4.2 shows that power[2] had a statistically significant difference for the CT group when comparing the post-control and post-treatment means. Similarly, the pre-control to pre-treatment reflected a statistically significant difference in means. The TC group at pre-control was statistically significantly different when compared to the post-control, as well as post-treatment. Both post-control and post-treatment reflected a difference in means. Local muscular endurance[2] indicated a statistically significant difference between the CT and TC group: the pre-control means were statistically significantly different to the pre-treatment means. Local muscular endurance[3] also revealed a statistical significant difference between the CT and TC groups' pre-control and pre-treatment mean. Both the post-control and post-treatment indicated differences, which were significantly different. Additionally, local muscular endurance[4] showed a statistical significant difference between the CT and TC groups' pre-control and pre-treatment means. A difference was noted in both the CT and TC groups' post-control and post-treatment means, which were significantly different.

Table 4.2: Bio-motor skills which showed a statistically significant difference ($p=\leq 0.05$) when comparing pre- and post-control (no treatment), and pre- and post-treatment ($M \pm SD$) in the different treatment groups (CT and TC).

Bio-motor skill	Group	Pre-control n= 16	Post-control n= 10	Pre-treatment n= 15	Post-treatment n= 13
Power[1]	CT	4.71 ± 1.26^{a}	4.60 ± 1.07^{abc}	4.38 ± 0.64^{bc}	4.68 ± 0.58^{abc}
	TC	4.33 ± 0.77^{c}	5.04 ± 0.65^{abc}	4.83 ± 1.26^{ab}	4.81 ± 1.05^{ab}
Power[2]	CT	2.81 ± 0.13^{abcd}	2.80 ± 0.13^{cd}	2.81 ± 0.10^{a}	2.84 ± 0.15^{ab}
	TC	2.82 ± 0.10^{ac}	2.76 ± 0.09^{d}	2.80 ± 0.13^{abcd}	2.78 ± 0.13^{bd}
Local muscular endurance[2]	CT	47.50 ± 16.64^{c}	48.30 ± 16.45^{c}	64.76 ± 15.85^{b}	62.10 ± 16.43^{b}
	TC	74.65 ± 23.32^{a}	77.80 ± 25.02^{a}	47.63 ± 14.03^{c}	46.00 ± 14.80^{c}
Local muscular endurance[3]	CT	8.00 ± 5.13^{cd}	8.58 ± 5.33^{bcd}	11.94 ± 6.67^{ab}	10.17 ± 9.22^{abcd}
	TC	11.79 ± 5.61^{a}	12.44 ± 6.67^{abc}	7.29 ± 5.04^{d}	10.75 ± 6.59^{ab}
Local muscular endurance[4]	CT	32.17 ± 20.79^{e}	42.34 ± 22.73^{bd}	54.32 ± 24.34^{ac}	49.92 ± 39.35^{abcd}
	TC	50.31 ± 22.42^{ab}	46.09 ± 16.46^{abcd}	39.06 ± 26.17^{cde}	43.05 ± 14.72^{cd}

Note: CT - control-treatment; TC – treatment control; Superscripts are used to indicate statistically significant differences. Where superscripts are different, it indicates the degree of difference between means. I.e., If 4.71 ± 1.26^{a} and 4.60 ± 1.07^{abc} are compared, this indicates a statistically significant difference ($p=\leq 0.05$).

Figure 4.2 shows the specific directions, which indicated statistically significant differences ($p = \leq 0.05$) between the control and treatment period. According to Figure 4.2, the medial, lateral and posterolateral directions all significantly improved from before control to after control ($p = \leq 0.05$). Similarly, the directions anteromedial, posteromedial and posterior improved from before treatment to after treatment ($p = \leq 0.05$).



	Before control	After control	Before treatment	After Treatment
Anterior	67,07	68,30	65,11	69,56
Anteromedial	67,74	68,11	65,18	69,91
Medial	63,55	67,26	62,76	68,23
Posteromedial	66,73	67,16	64,42	68,62
Posterior	65,02	65,27	64,55	67,12
Posterolateral	65,24	62,62	62,20	66,07
Anterolateral	65,17	63,33	63,94	65,09

*Note: *Statistically significant difference ($p = \leq 0.05$).*

Figure 4.2: Star Excursion Balance test (SEBT) statistically significant means for each reach direction between control and treatment time periods.

Table 4.3 below indicate those bio-motor skills, which showed a statistically significant difference ($p = \leq 0.05$) when comparing pre- and post-control (no treatment) and pre- and post-treatment (M ± SD) when comparing forwards and backs. Agility[1] for the forwards in the TC group reported different means when comparing pre-control to post-control. A statistically significant difference ($p = \leq 0.05$) was observed between pre- and post-treatment mean scores. The forwards in the CT group reported a statistically significant difference between pre-control and pre-treatment mean scores. The backs in the TC group, showed a difference between pre- and post-control. Furthermore, the CT group showed a statistically significant difference ($p = \leq 0.05$) between pre- and post-control. Power[1] mean scores pre-treatment compared to post-treatment also indicated a statistically significant difference.

Table 4.3: Bio-motor skills which showed a statistically significant difference ($p = \leq 0.05$) when comparing pre- and post-control (no treatment), and pre- and post-treatment ($M \pm SD$) when comparing forwards and backs.

Bio-motor skill	Positional group	Group	Pre-control n= 16	Post- control n= 10	Pre – treatment n= 15	Post – treatment n= 13
Agility[1]	Forwards n=21	CT	17.21 ± 1.18^{ab}	16.85 ± 0.93^{abc}	16.09 ± 0.29^{abcde}	16.82 ± 0.79^{abc}
		TC	17.55 ± 1.45^{a}	16.52 ± 0.81^{abcd}	17.60 ± 2.49^{ab}	16.71 ± 0.86^{de}
	Backs n=33	CT	17.06 ± 2.40^{ab}	16.15 ± 0.53^{cde}	16.65 ± 1.80^{bcde}	15.80 ± 0.76^{de}
		TC	16.46 ± 1.83^{bcde}	16.15 ± 0.60^{cde}	15.93 ± 1.24^{de}	15.88 ± 0.69^{de}
Power[1]	Forwards n=21	CT	5.45 ± 1.22^{ab}	5.04 ± 1.20^{abcde}	4.66 ± 0.62^{cdefghi}	4.94 ± 0.74^{abcdef}
		TC	4.58 ± 0.73^{befghi}	5.08 ± 0.76^{abcdefh}	5.22 ± 1.33^{ac}	5.20 ± 1.05^{acd}
	Backs n=33	CT	4.31 ± 1.10^{fghi}	4.32 ± 0.90^{efghi}	4.23 ± 0.62^{hi}	4.51 ± 0.40^{cdefg}
		TC	4.10 ± 0.76^{gi}	4.99 ± 0.59^{efghi}	4.51 ± 1.14^{efghi}	4.50 ± 0.97^{defh}

Note: CT - control-treatment; TC – treatment control; Superscripts are used to indicate statistically significant differences. Where superscripts are different, it indicates the degree of difference between means. Ie. If 4.71 ± 1.26^{a} *and* 4.60 ± 1.07^{abc} *are compared, this indicates a statistically significant difference (*$p \text{-} \leq 0.05$*).*

Table 4.4: Bio-motor skills which did not show a statistically significant difference (p=>0.05) when comparing pre- and post-control (no treatment), and pre- and post-treatment (M ± SD) in the different treatment groups.

Bio-motor skill	Pre-control n=16	Post- control n=10	Pre – Treatment n=15	Post – Treatment n=13
Agility[1]	17.07 ± 1.90[a]	16.40 ± 0.76[b]	16.61 ± 1.94[b]	16.26 ± 0.88[b]
Agility[2]	16.85 ± 1.49[a]	16.34 ± 0.83[bc]	16.51 ± 1.23[ab]	15.99 ± 1.97[c]
Flexibility	33.58 ± 8.61[a]	34.97 ± 7.26[a]	34.51 ± 9.30[a]	35.38 ± 8.56[a]
Local muscular endurance[1]	49.55 ± 16.47[a]	46.08 ± 19.49[a]	45.25 ± 16.36[a]	48.59 ± 18.02[a]

Note: Note: Superscripts are used to indicate statistically significant differences. Where superscripts are different, this indicates the degree of difference between means. Ie., If 4.71 ± 1.26[a] and 4.60 ± 1.07[abc] are compared, it indicates a statistically significant difference (p-≤0.05).

According to the results showed in Table 4.4, agility[1] indicated no statistically significant difference between post-control and pre-treatment, as well as from pre- to post-treatment. Agility[2], however, showed differences for all 4 treatment times. The post-treatment mean scores for agility[1] was significantly different to all the other mean scores in the various treatment times. Flexibility and local muscular endurance[1] had no statistically significant difference (p=>0.05) across the 4 treatment times as indicated by their mean scores, which remained unchanged.

	Anterior	Posterior	Medial	Lateral	Anterolateral	Anteromedial	Posterolateral	Posteromedial
Backs	66,27	64,14	63,39	55,54	63,25	66,89	63,45	65,79
Forwards	68,75	66,84	67,52	58,06	65,52	68,58	64,61	67,67

Figure: 4.3: Star Excursion Balance test (SEBT) means for each reach direction, which did not show a statistically significant difference (p>0.05).

As evident from Figure 4.3, the mean scores for reach directions were the same between the forwards and backs. None of the reach distances showed a statistically significant difference between the two positional groups.

Table 4.5 indicates that forwards did not show significant improvements (p=>0.05) in the following treatment times: In agility[1], there was no significant difference between pre- and post-control. For flexibility, there were no significant differences between pre- and post-control or pre- and post-treatment. Furthermore, there was no significant difference in the mean scores of power[2] between pre-control and pre-treatment, as well as no significant difference in mean scores between pre- and post-treatment. Local muscular endurance[1] showed no significant difference between pre- and post-control. In summary, the forwards did not show improvements in agility[2] at post-control or post-treatment, no statistically significant differences in flexibility and no significant differences in power[2], as well as local muscular endurance[4] from pre- to post-treatment.

Table 4.5: Bio-motor skills which did not show a statistically significant difference ($p=\leq 0.05$) when comparing pre- and post-control (no treatment), and pre- and post-treatment ($M \pm SD$) when comparing forwards and backs.

Bio-motor skill	Position	Pre-control n=16	Post- control n=10	Pre – Treatment n=15	Post – Treatment n=13
Agility[2]	Forwards	17.60 ± 1.65^{a}	16.73 ± 0.89^{b}	16.88 ± 1.08^{ab}	16.79 ± 0.89^{b}
	Backs	16.35 ± 1.13^{bc}	16.06 ± 0.67^{c}	16.27 ± 1.28^{bc}	15.36 ± 2.35^{d}
Flexibility	Forwards	32.52 ± 9.24^{a}	32.52 ± 9.24^{a}	35.89 ± 7.17^{a}	34.84 ± 11.45^{a}
	Backs	34.34 ± 8.19^{a}	34.19 ± 7.42^{a}	34.29 ± 7.74^{a}	35.63 ± 6.61^{a}
Power[2]	Forwards	2.82 ± 0.13^{ab}	2.77 ± 0.16^{b}	2.82 ± 0.13^{a}	2.83 ± 0.15^{a}
	Backs	2.80 ± 0.11^{ab}	2.80 ± 0.07^{ab}	2.79 ± 0.11^{ab}	2.78 ± 0.14^{ab}
Local muscular endurance[1]	Forwards	43.32 ± 15.52^{bcd}	41.44 ± 16.84^{bcd}	39.59 ± 13.93^{d}	43.65 ± 11.17^{cd}
	Backs	54.00 ± 17.64^{a}	49.80 ± 21.05^{ab}	49.40 ± 16.97^{abc}	52.38 ± 21.33^{a}
Local muscular endurance[2]	Forwards	53.00 ± 21.13^{cd}	55.50 ± 20.13^{ab}	48.36 ± 13.25^{cd}	47.76 ± 17.22^{d}
	Backs	63.14 ± 24.90^{a}	56.86 ± 25.42^{ab}	56.80 ± 18.08^{bc}	56.18 ± 16.73^{bcd}
Local muscular endurance[3]	Forwards	8.08 ± 6.10^{cd}	8.56 ± 6.54^{abcd}	6.09 ± 4.07^{d}	8.55 ± 7.16^{bcd}
	Backs	10.62 ± 5.05^{ab}	10.42 ± 5.25^{abc}	10.80 ± 6.41^{a}	12.04 ± 7.77^{a}
Local muscular endurance[4]	Forwards	38.10 ± 25.42^{b}	40.00 ± 16.75^{ab}	39.95 ± 27.65^{ab}	42.90 ± 16.65^{ab}
	Backs	40.71 ± 21.54^{b}	46.31 ± 24.06^{ab}	47.20 ± 25.36^{a}	47.78 ± 32.69^{b}

Note: Superscripts are used to indicate statistically significant differences. Where superscripts are different, this indicates the degree of difference between means. I.e., If 4.71 ± 1.26^{a} *and* 4.60 ± 1.07^{abc} *are compared, it indicates a statistically significant difference (*$p\text{-}\leq 0.05$*).*

The backs did not show significant improvements in the following bio-motor skills: agility[2], no significant differences were observed between pre-control and pre-treatment. For flexibility and power[2], no significant differences were found between pre-control and pre-treatment phases. Furthermore, local muscular endurance[1] showed no significant differences between pre-control and post-treatment, local muscular endurance[2] showed no significant differences between pre- to post-control and between pre- to post treatment times, local muscular endurance[3] indicated no differences from pre- to post-control, as well as from pre-to post-treatment. Similarly, mean scores for local muscular endurance[3] showed no difference between post-control and post-treatment. Finally, local muscular endurance[4] remained unchanged at post-control, as well as pre-treatment to post-treatment. In summary, flexibility and power[2] did not show any statistical significant improvement. Particularly from pre- to post-treatment, the backs showed no significant differences in local muscular endurance[2, 3 & 4].

4.5 Discussion

According to the researcher's knowledge, this is the first study to investigate the effect of a rhythmic movement intervention on selected bio-motor skills among academy rugby players. The primary aim of the study was to investigate the effect of a rhythmic movement intervention on selected bio-motor skills of academy rugby players in the Western Province Rugby Union. The specific objectives were: to investigate the effect of a rhythmic movement intervention on flexibility, dynamic balance, agility, power and local muscular endurance of academy rugby players and to compare the selected bio-motor skills of backs and forwards after participating in a 16-week rhythmic movement intervention. In summary amongst the entire sample of participants, power[1, 2] and local muscular endurance[2,3,4] , as well some dynamic balance directions (anterior, anteromedial, posteromedial, posterior, posterolateral direction and medial), were the only bio-motor skills, which showed statistically significant improvements ($p=\leq 0.05$) from pre to post-treatment. Amongst forwards and backs agility[1] and power[1] showed statistically significant improvements ($p=\leq 0.05$).

The results revealed a statistical significance ($p=\leq 0.05$) difference for power and local muscular endurance when compared to pre- and post-control and pre- and post-treatment. More specifically, according to the data, the bio-motor skills, which showed statistically significant improvements from pre-treatment to post-treatment included power[1 & 2] and local muscular endurance[2, 3 & 4]. The power[1, 2] bio-motor skills showed improvements during the time of the intervention. This finding corresponds with finding of Barr *et al.* (2014) who notes that lower body power specifically can help to improve sprinting ability through improving general maximal strength. The current rhythmic movement study's results only reflects one part of the finding from Barr *et al.* (2014) because lower body power did improve, but no statistically significant difference was seen in agility. In a study by Kloubec *et al.* (2010), improvements in local muscular endurance were found following pilates exercises for two 60-minute sessions per week over a 12-week period. From this, the primary researcher could deduce that a higher intensity, multi-faceted rhythmic movement intervention over 16 weeks (two, 8-week periods), has potential to improve muscular endurance. In agreement with Kloubec *et al.* (2010), the findings of the current study revealed a statistically significant improvement in local muscular endurance[2, 3 & 4] after the intervention was implemented.

Table 4.4 indicate significantly different results ($p=\leq0.01$), which shows improvements from pre to post-treatment. These bio-motor skills included agility[1] amongst the forwards who showed significant improvements in the TC group (from 16.65 ± 1.80^{bcde} to 15.80 ± 0.76^{de}). The backs showed a significant difference in the CT group from pre- to post-treatment. These results are in agreement with Jarvis *et al.* (2009) who found that playing-position differences existed regarding agility performance. The results of the latter study revealed that backs produced significant correlations ($P=<0.05$) compared to forwards regarding agility. Furthermore, when power[1] was tested, both forwards and backs in the CT group showed a significant difference ($p=<0.01$) from pre- to post-treatment in the current study.

According to Duthie *et al.* (2003), there are clear differences in the physiological and anthropometric traits of backs and forwards. Forwards and backs in the current study, showed different amounts of improvements across the bio-motor skills, which may allude to positional differences during match play. The current study found a statistically significant difference in terms of power[1], which is a positive indicator that backs and forwards have different relative and absolute power in agreement with findings from Barr *et al.* (2014). In agreement with Duthie *et al.* (2003) and Durandt (2006), positional differences do exist between these two groups and they need to be trained accordingly. The difference between the backs and the forwards can be because of the different roles they fulfil in a game. Compared to backs, forwards experience sustained higher contact loads per match because of activities, such as tackles, rucks and mauls (Quarrie *et al.,* 2013). They require different physical conditioning because of the number of impacts in the game (Sirotic *et al.,* 2011). This could also be attributed to the difference in height and weight as revealed by the player characteristics of the current study. As noted by Quarrie *et al.* (2013), it is evident that each position (therefore, forwards and backs), has specific functional roles during match play, as well as bio-motor skill requirements and therefore, requires specific fitness and conditioning components to suite these various requirements.

4.5.1 Practical application

In terms of the practical application of the current study, rhythmic movement is an easy and fun alternative method for training bio-motor skills. The benefits of music in sport and exercise have reflected benefits of music in terms of mood, affect and cognition (psychological), psychophysical effects (perception of physical effort), psycho-physiological (heart and respiration rate), and ergogenic effects. Athletes like Michael Phelps (7-time gold medal winner and 5-time world record holder at the 2007 FINA World Championship), reportedly listens to hip-hop music before his races as the beat and lyrics help to get him psyched up and focussed. Music improves performance by either delaying fatigue or increasing work capability. This in turn leads to higher expected levels of power, strength, endurance or productivity (Terry *et al.,* 2012). Furthermore, studies have reported the existence and importance of rhythm in sport skills. Söğüt, *et al.* (2012) reports that sense of rhythm applies to ball games, which helps develop attitudes of calmness and fluency for performers. Lastly, it was found that rhythmic abilities facilitate success in ballet (Côté-Laurence, 2000). Rhythmic movement can be adapted in various ways in terms of music and movement to accommodate not only the rugby players, but also rugby-orientated movements. Additionally, a rhythmic movement intervention can be used right throughout the season with adaptations to intensity according to the demands of the training phase. For this reason, multiple bio-motor skills can be trained simultaneously, which is advantageous to a demanding rugby-training schedule. In other words, rhythmic movement can be used as a tool to warm-up, as a conditioning method to improve specific bio-motor skills or, when required, as a recovery method for players.

4.6 Conclusion

Overall, the lack in performance improvement and often minimal change in performance regarding bio-motor skills, may allude to the treatment on its own being inefficient in its ability to target improvement in specific bio-motor skills over the short period of time. Additionally, the improvement subsequent to no treatment may indicate that the rugby academies conditioning programme had an effect on the bio-motor skills, while the rhythmic movement treatment was not implemented.

Each of the rugby academies approached for the study, had individual schedules and rugby conditioning programmes for their players. Time for the intervention, as well as testing days were limited as the rugby programmes were already engaged in tactical and technical sessions. Thus, there were various different influences with direct and indirect effects for the intervention itself, which the researcher could not control. Because of this being a novel study, the researcher had no previous knowledge or insights as to which rhythmic movements would work well to illicit change or improve performance in bio-motor skills, what type of music would be easy for the participants to perform the movements to and more importantly, how long it would take for each specific bio-motor skill to show improvement. However, where differences did occur in particular bio-motor skills, these were statistically significant not only amongst the entire group of participants, but also when considering positional group differences.

The study reflected 3 outcomes: 1) the intervention was effective in improving some bio-motor skills (at the time when treatment was implemented): 2) where improvements did occur, it could not be (solely) attributed to the intervention; and 3) there is potential for positional group improvement in performance of selected rugby bio-motor skills if the intervention is designed with positional groups in mind. The results from this study highlighted the importance for further research on the effect of rhythmic movement for rugby bio-motor skills. Research first needs to determine which types of rhythmic movements will contribute more effectively to rugby specific bio-motor skills. Thereafter, a rhythmic movement intervention based on the specific rugby related rhythmic movements can be compiled and implemented. Studies should investigate not only the effect of rhythmic movement on improving specific rugby bio-motor skills, but also utilise it as an alternative training method during off-season (or detraining phases) and as a recovery method. Limitations of the study include the small sample size, the limited amount of time (only 2 hours per week of rhythmic movement sessions), the fact that the intervention was only implemented at one phase of the season, as opposed to throughout the entire rugby season and that the content of the session were not designed to accommodate positional specific demands and bio-motor skills.

4.7 Acknowledgement

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4.8 Disclosure statement

4.8.1 Disclosure of interest

The authors report no conflict of interest.

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CHAPTER 5

SUMMARY, CONCLUSIONS, LIMITATIONS AND FUTURE RESEARCH

This chapter is included herewith in accordance with the referencing style of the Department of Sport Science, Stellenbosch University.

5.1	**SUMMARY**	**109**
5.2	**CONCLUSIONS**	**110**
5.3	**LIMITATIONS**	**111**
5.4	**FUTURE RESEARCH**	**112**
5.5	**REFERENCES**	**113**

SUMMARY

Numerous literatures are available on various training methods used in different sporting codes. In terms of strength and conditioning in rugby ample literature is available on the traditional approaches to rugby training and how these forms of training contribute positively to rugby specific bio-motor skills (such as speed and agility). However, there is limited research surrounding the effect of rhythmic movement as a training method in rugby. The current study aimed to show the effect of a 16-week rhythmic movement intervention on selected bio-motor skills of Western Province Rugby Union Academy players.

The specific objective of the current study was to investigate the effect of a 16-week rhythmic movement intervention on flexibility, dynamic balance, agility, power and local muscular endurance of the above-mentioned rugby players. The study was presented in four main parts, namely: an introduction and problem statement (Chapter One); theoretical context (Chapter 2); methodology (Chapter 3); a research article (Chapter 4); and the summary, limitations and future research (Chapter 5). The thesis is presented according to the guidelines of the Department of Sport Science and the research article is presented in accordance with the guidelines of the specific journal.

In Chapter One the problem statement, primary aim and the objectives of this study are introduced. In Chapter Two a theoretical context is provided on the available literature on strength and conditioning, traditional training methods in rugby, bio-motor skills and rhythmic movement. The literature revealed many of the traditional methods to rugby training, such as gymnasium- and field-based exercises (i.e., weight lifting, agility and speed drills, plyometric and strength training). Furthermore, the literature highlighted the benefits of these methods of training. Additionally, it showed that there is a gap for alternative means of training to improve bio-motor skills, especially because rugby is a dynamic sport and demands different facets of fitness to be trained simultaneously. The benefit of rhythmic movement in the psychomotor domain was more prevalent than that in the physical domain, particularly in terms of its effect on improving bio-motor skills in other sports. However, benefits of rhythmic movement interventions were found in studies that focussed on soccer players.

The research methodology is presented in Chapter Three. Specific reference was made to the use of a crossover experimental research design. The main purpose of the current study design was to provide a basis for separating treatment-effects from period-effects and to establish whether the intended outcome(s) of the intervention have materialised (Dwan *et al*., 2019:2).

This meant that the intervention was divided into two periods namely "treatment-control" and "control-treatment" where one group received the treatment in the first 8 weeks (TC[A]) and the other group received treatment in the second 8-weeks (CT[B]) of the intervention. Furthermore, the timeline of the study was explained, as well as a description of the participants, exclusion and inclusion criteria, the data collection procedure and the testing procedure that was followed.

Chapter Four is presented in a research article format, entitled: *The effect of a rhythmic movement intervention on selected bio-motor skills of Western Province Rugby Union academy players*. A positive treatment effect on the bio-motor skills was defined by a statistically significant increase in performance after treatment was implemented based on the treatment-order and treatment time interaction. The results indicated the following: among the entire sample of participants power[1 & 2] (seated medicine ball throw and vertical jump and local muscular endurance[2, 3 & 4](2-minute crunch, pull-up to failure and single leg squat to failure), as well some dynamic balance directions (anterior, anteromedial, posteromedial, posterior, posterolateral direction and medial), were the only bio-motor skills that showed statistically significant improvements ($p=\leq 0.05$) from pre to post-treatment. When the forwards and backs were compared, agility[1] and power[1] revealed statistically significant improvements ($p=\leq 0.05$).

CONCLUSIONS

The conclusions drawn from this study were presented in accordance to the set objectives and hypothesis set out in Chapter One.

Research Article 1: The effect of a rhythmic movement intervention on selected bio-motor skills of Western Province Rugby Academy players. A major finding of this study was that with treatment implemented statistically significant difference was observed in the following bio-motor skills: agility, power, local muscular endurance and some dynamic balance directions. Power[1, 2] showed statistically significant improvements, which are in agreement with findings by Barr *et al*. (2014) who notes that lower body power can help to improve sprinting ability through improving general maximal strength. The current study's results only reflects one part of the finding from Barr *et al*. (2014) as lower body power did improve significantly but no statistically significant difference was found in agility amongst the entire sample size. However, when the most significant results ($p=\leq 0.01$) were compared among the forwards and backs, it included agility[1] among the forwards. Forwards showed a significant difference (an improvement) in the TC group (from 16.65 ± 1.80^{bcde} to 15.80 ± 0.76^{de}), and the backs showed significant difference in the CT group from pre- to post-treatment. These results are in agreement with Jarvis *et al*. (2009) who found that playing-position differences existed regarding agility performance. The results of the study performed by Jarvis *et al*. (2009), revealed that backs produced significant correlations (p=<0.05) compared to forwards when testing agility. In a study by Kloubec (2010), improvements in local muscular endurance were seen following pilates exercise for two 60-minute sessions per week over a 12-week period. From this, the primary researchers of the rhythmic movement study could deduce that a higher intensity, multi-faceted rhythmic movement intervention over two 8-week periods has the potential to improve muscular endurance. In agreement with Kloubec (2010), findings of the current study revealed a statistically significant improvement in local muscular endurance[2, 3 & 4] after the intervention was implemented. Overall, the lack in performance improvement and often minimal changes in performance regarding bio-motor skills, may indicate that the treatment itself was inefficient in improving specific bio-motor skills over the short period of time. Additionally, the improvement subsequent to no treatment may indicate that the academies' rugby conditioning programmes had an effect on the bio-motor skills, while the players were not exposed to the intervention.

From the results, the current study reflected 3 outcomes, namely: 1) the intervention was effective in improving some bio-motor skills (at the time when treatment was implemented); 2) where improvement did occur it could not be (solely) attributed to the intervention; and 3) there is potential for positional group improvements in performance of selected rugby bio-motor skills if the intervention is designed with positional groups in mind.

Hypothesis: After participating in a 16-week rhythmic movement intervention, selected bio-motor skills of academy rugby players in the Western Province Rugby Union will improve.

Accept: Significant differences were observed in most of the selected bio-motor skills including when forwards and backs were compared.

LIMITATIONS

The following limitations with reference to this study are stated below:

- The sample size was small and did not allow the primary researcher to split the groups into more specific positional groups. Hence, a crossover design was followed in the study.

- The intervention was generic for both forwards and backs. Therefore, rhythmic movements were not specific, but mimicked general rugby movements.
- The duration of the intervention was short (split into two 8-week periods) because it was only implemented during the pre-season period.
- Due to this study being the first of its kind, there was no reference as to what type of rhythmic movements could/should be used during the intervention in order to closely mimic rugby movements and have the best treatment-effect.

FUTURE RESEARCH

The results from this study highlight the importance of further research on the effect of rhythmic movement on rugby bio-motor skills. A rhythmic movement intervention, based on specific rugby related rhythmic movement, can be compiled and implemented. Studies should investigate not only the effect of rhythmic movements on improving specific rugby bio-motor skills, but also the psychological and psychophysical benefits of music on performance. A rhythmic movement intervention, such as this will assist coaches (including strength and conditioning coaches), who are frequently searching for innovative ways to improve performance to implement an original training strategy to their strength and conditioning programmes, not necessarily as a substitute, but as a supplementary.

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APPENDIX A

INFORMED CONSENT FORM

UNIVERSITEIT•STELLENBOSCH•UNIVERSITY
jou kennisvennoot • your knowledge partner

STELLENBOSCH UNIVERSITY
CONSENT TO PARTICIPATE IN RESEARCH

A rhythmic movement intervention for academy rugby players in the Western Province rugby union.

You are asked to participate in a research study conducted by Wilbur Kraak (PhD), Eileen Africa (PhD), and Jocelyn Solomons (MSc student) from the Department of Sport Science at Stellenbosch University. You were selected as a possible participant in this study because you are playing competitive rugby at an amateur level.

1. AIM OF THE STUDY

The primary aim of the study is to investigate the effect of a rhythmic movement intervention on bio-motor abilities of selected amateur rugby players in the Western Cape. Subsequently, the specific objective is to incorporate these characteristics into a rhythmic movement (dance) intervention programme as a method to improve the bio-motor variables (e.g., flexibility, balance, agility, power and endurance) of rugby players.

2. PROCEDURES

If you volunteer to participate in this study, we would ask you to do the following things:

Both the experimental and control groups will perform pre-tests, which measure their flexibility, dynamic balance, agility, power and local muscular endurance. The control group will not participate in the rhythmic movement programme planned for the experimental group. They will only participate in a pre-, mid- and post- intervention test and will proceed with their usual rugby training programme. The experimental group will take part in a rhythmic movement programme that will consist of movement choreography, specifically designed to incorporate movements to enhance the specific bio-motor variables.

3. POTENTIAL RISKS AND DISCOMFORTS

There are no serious risks involved in the study. The researcher is trained in First Aid. You may be uncomfortable during the higher intensity activities and may also experience muscle soreness and perspiration after the exercise sessions. The requirements during the intervention programme will not be strenuous or harmful to your body.

4. POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

The researchers are aiming to achieve the following results:

- Improve flexibility of rugby players.
- Improve dynamic balance of rugby players.
- Improve agility of rugby players.
- Improve power of rugby players.
- Improve local muscular endurance of rugby players.

5. PAYMENT FOR PARTICIPATION

No payment will be received for participation.

6. CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Confidentiality will be maintained by means of a confidentiality agreement made between the participants and the researchers. Data collected from the study will be stored on a password protected computer and only the researchers involved in this study will have access to data collected.

7. PARTICIPATION AND WITHDRAWAL

Participation is encouraged in order to enhance knowledge in this field of research as well as to provide personal gain for you from the results found. If you volunteer to participate in this study, you can refuse to answer any questions you do not wish to answer and still remain in the study. The researchers may withdraw you from this study if circumstances arise which warrant doing so. Termination by the researchers could occur if you fail to attend testing procedures on more than one of the testing days provided. If you become ill or injured withdrawal will occur for your own wellbeing.

8. IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about the research, please feel free to contact Wilbur Kraak (kjw@sun.ac.za; 021 808 2379), Eileen Africa (africa@sun.ac.za; 021 808 4915); and Jocelyn Solomons (18520286@sun.ac.za; 021 808 2379)

9. RIGHTS OF RESEARCH SUBJECTS

You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research subject, contact Ms Maléne Fouché [mfouche@sun.ac.za; 021 808 4622] at the Division for Research Development.

SIGNATURE OF RESEARCH SUBJECT OR LEGAL REPRESENTATIVE

The information above was described to ____by Wilbur Kraak, Eileen Africa and Jocelyn Solomons in English and I am in command of this language or it was satisfactorily translated to me. I was given the opportunity to ask questions and these questions were answered to my satisfaction.

I hereby consent voluntarily to participate in this study and I have been given a copy of this form.

___________________________________ _______________________

Name of Subject/Participant **Date**

____

Signature of Subject/Participant

SIGNATURE OF INVESTIGATOR

I declare that I explained the information given in this document to ___________________________________. He was encouraged and given ample time to ask me any questions. This conversation was conducted in English.

____________________________________ _________________________

Signature of Investigator **Date**

APPENDIX B
TESTING PROTOCOL

Participant number (for office use only)	
Age	
Sporting Code	
Position / Jersey Number	
Are you injured? (Yes/ No) - describe	
Testing date	

Biometrics					
Weight					
Height					
Flexibility					
Sit-and-reach	1	2	3		
Dynamic Balance - SEBT					
Bottom of sheet					
Agility					
Illinois (without ball)	Left	Right			
Illinois (with ball)	Left	Right			
Power					
Vertical Jump (3 x)	Reached Height	1	2	3	
Seated Medicine Ball throw (2x)	1	2			
Local Muscular endurance					
1 minute Push Up test	1				
2 min Crunch Test (APFT)	1				
Pull up (to failure)	1				
Single leg Squat (to failure)	Left	Right			

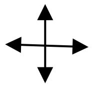
	Ant (R)	Ant (L)	**Ant Med**	Ant Lat	**Med**	Lat	**Post Med**	Post Lat	**Post**	Post	**Post Lat**	Post Med	**Lat**	Med	**Ant lat**	Ant Med
REACH DIST (cm)																

APPENDIX C
RHYTHMIC MOVEMENT INTERVENNTION SESSIONS WEEKS 2-9

The purpose of the first 8 weeks is to expose the participants to various movements, targeting the lower body. These movements are ballet orientated and require lower body endurance, power, strength and flexibility. Counts per minute of music should be between 90-100 BPM.
The local muscular endurance rhythmic movements remain the same throughout both 8-week periods.

KEY

Right Leg - RL
Forward - FWD
Left Leg - LL
Backward - BWD
Both sides – BS
Simultaneously - +
Half circle - HC
Up - U
Full circle - FC
Down - D

Timing (as per each side)	Body part (bold)	Description / note
• **2 beats per tap*, 4 x on RL** • **Repeat on LL** • **FWD, side and BWD**	1. Legs and toes 	1. Tap forward with the toe, remembering to push through with the heel and bring back with the toes (turn out). 2. *2 beats per tap = 1 beat to point forward + 1 beat to recover. Repeat the required repetitions at each direction before changing directions and swopping to the other side.
• **2 beats on the kick, 2 beats to lower** • **Repeat on LL** • **FWD, side and BWD**	3. **Legs, and core** **<u>Wall</u>**	1. The supporting leg should be straight at all times. 2. The kicking leg should be pointed and slightly turned out from the hip. 3. Attempt a lift as close to 90 degrees as possible, but only go as far as comfortable with the height of the lifting leg.
• **2 beats on each *develope'*, 2 beats to lower, 4 x** • **Repeat on LL** • **FWD, side and BWD**	1. *Develope's* on each side, and each leg 2. ***develope'* – "to develop"** **<u>Wall</u>**	1. The leg develops from a bent knee to a straight leg, recover (lower). 2. Remember the turnout once the leg is straightened, hips squared. 3. Repeat the required repetitions at each direction before changing directions and swopping to the other side.
• **4 x 8 beats per HC**	- From a *develope'* legs make a HC (a.k.a *ronde jambe a terre*) 1. and recover	1. Remember turn out from the hip. 2. Legs should stay the same height throughout the HC.

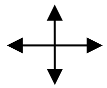
		3. Repeat the required repetitions at each direction before changing directions and swopping to the other side.
	<u>Jumps-</u> in 1st & 2nd position	
• **2 beats per jump x 15 jumps, repeat 2 x** • **Single leg jumps, 2 beats per jump x 12 per leg**	1. Double leg (first position) 2. Transition from RS to LS	1. Hands on hips, controlled jumps, through the feet (no sound) – jumps are slow. 2. “springbokkie” jumps – the aim is to get a pointed foot and also a ‘V’ shape with feet in the middle of transferring weight.

****local muscular endurance rhythmic movements shown and explained at the end of Weeks 16-23.***

RHYTHMIC MOVEMENT INTERVENTION SESSIONS WEEKS 16- 23

The purpose of the rest of the weeks is to increase the intensity and load of the session. Basic arm movements and a balance variation will be incorporated to target co ordination and balance. These movements tap in to the endurance, power, strength and flexibility bio-motor variables. Counts per minute of music should be between 90-130 BPM.

KEY
Right Leg - RL
Forward - FWD
Left Leg - LL
Backward - BWD
Both sides - BS
Simultaneously - +
Half circle - HC
Up - U
Full circle - FC
Down - D

Timing (as per each side)	Body part (bold)	Description / note
• **2 counts per tap, 4 x on RL** • **Repeat on LL** • **FWD, side and BWD**	2. Legs, glutes and feet 	4. Tap forward with the toe, remembering to push through with the heel and bring back with the toes (turn out).
• **2 counts on the kick, 2 counts to lower** • **Repeat on LL** • **FWD, side and BWD**	5. Legs, Glutes and core	4. The supporting leg should be straight at all times 5. The kicking leg should be pointed and turned out 6. Attempt a lift as close to 90 degrees as possible, but only go as far as comfortable with the height of the lifting leg.
	Glutes, core and feet: ***Plie's***	
• ***"Demi" and "Grande plie's"*** • **RS : 2 x 8 counts** • **LS : 2 x 8 counts**	1. First round will be *demi plie'* 2. Second round are *"grande plie's"*	1. Aim to keep the heels on the floor as long as possible. 2. Keep the glutes and core tight, heels come off the floor. 3. Use 6 counts to go lower, and 2 counts to recover.
	Wall	
	3. *Develope's* on each side, and each leg	4. The leg develops from a bent knee to a straight leg, recover. 5. Remember the turnout once the leg is straightened, hips squared.

• **2 counts on each *develope*', 2 counts to lower, 4 x** • **Repeat on LL** • **FWD, side and BWD**	**<u>Balance variation</u>**	
• **Step 1: 2 counts** • **Step 2: 2 counts** • **Step 3: 4 counts** • **Step 4: 4 counts** • **Step 5: 2 counts** • **Step 6: 4 counts** • **Step 7: 2 counts hold** • **Step 8: Recover** **Repeat 3 x on each side**	1. Stand on RF, bring up LS knee to 90 degrees 2. LL "open gate" 3. LL: from that position, extend leg from the knee fully 4. Tip body towards the floor 5. LL steps diagonal in front across body 6. Cont. sit on walk position 7. Recover by standing up	1. Arms stretch out **FWD** in front of body 2. Arms out to the side 3. Arms stay out to the side 4. Arms stay in line with body: end position should look like a leaning pyramid. 5. Arms stay to the side. 6. Controlled movement, no arms. 7. Controlled movement, no arms.

Lyrics	Moves Local Muscular endurance – Cha cha slide (in plank position)	Description
1. Clap your hands **2. (Slide) To the left** **3. Take it back** **4. One hop** **5. Left Foot lets stomp** **6. Right foot lets stomp** **7. Cha cha real smooth** **8. Turn it out** **9. REPEAT** **10. (slide) to the Left** **11. (sldie) to the Right** **12. Criss cross** **13. Let's go to work** **14. Hands on your knees**	1. Twists with the hips 2. Move to LS 3. Move back 4. Hop feet towards hands, and recover 5. LF only, comes in towards Left Hand/arm 6. RF only, comes in towards Right Hand/arm 7. Open and Close Gait (RS, then LS) 8. Two Push ups 9. (12) Criss cross feet (open and close) 10. (13) Hold plank position 11. (14) Opposite hand reaches t touch opposite knee	1. Plank position, core tight, glutes squeezed. 2. Left hand and Foot moves over to LS, followed by RF and RL. 3. Crawl back 4. Bring feet in towards hands

APPENDIX D
ETHICAL CLEARANCE LETTER

UNIVERSITEIT
STELLENBOSCH
UNIVERSITY

NOTICE OF APPROVAL

REC Humanities New Application Form

22 June 2018

Project number: 7111

Project Title: The effect of a rhythmic movement intervention on specific bio-motor abilities of Western Province rugby academy players

Dear Dr. Eileen Africa

Your REC Humanities New Application Form submitted on 30 May 2018 was reviewed and approved by the REC: Humanities. Please note the following for your approved submission:

Ethics approval period:

Protocol approval date (Humanities)	Protocol expiration date (Humanities)
22 June 2018	21 June 2021

GENERAL COMMENTS:

Please take note of the General Investigator Responsibilities attached to this letter. You may commence with your research after complying fully with these guidelines.

If the researcher deviates in any way from the proposal approved by the REC: Humanities, the researcher must notify the REC of these changes.

Please use your SU project number (7111) on any documents or correspondence with the REC concerning your project.

Please note that the REC has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

FOR CONTINUATION OF PROJECTS AFTER REC APPROVAL PERIOD

Please note that a progress report should be submitted to the Research Ethics Committee: Humanities before the approval period has expired if a continuation of ethics approval is required. The Committee will then consider the continuation of the project for a further year (if necessary)

Included Documents:

Document Type	File Name	Date	Version
Informed Consent Form	Appendix B Informed consent	26/04/2018	Informed consent
Data collection tool	Appendix A Testing protocol	26/04/2018	Testing protcol
Research Protocol/Proposal	18520286 J SOLOMONS MSc Protocol (June)	30/05/2018	2
Default	Reviewer feedback 18520286 J SOLOMONS MSc June	30/05/2018	1

If you have any questions or need further help, please contact the REC office at cgraham@sun.ac.za. Sincerely,
Clarissa Graham

REC Coordinator: Research Ethics Committee: Human Research (Humanities)

APPENDIX E

JOURNAL OF SPORTS SCIENCES
Manuscript Submission Guidelines: Journal of Sports Sciences

About the Journal

Journal of Sports Sciences is an international, peer-reviewed journal publishing high-quality, original research. Please see the journal's Aims & Scope for information about its focus and peer-review policy.

Please note that this journal only publishes manuscripts in English.

Journal of Sports Sciences accepts the following types of article: Original Articles, Case Studies, Letters to the Editor, Systematic Reviews and Meta-analysis.

The Journal of Sports Sciences is published on behalf of the British Association of Sport and Exercise Sciences, in association with the International Society for Advancement of Kinanthropometry. The emphasis is on the human sciences applied to sport and exercise. Topics covered also include technologies such as design of sports equipment, research into training, and modelling and predicting performance; papers evaluating (rather than simply presenting) new methods or procedures will also be considered.

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Preparing Your Paper

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Structure

Your paper should be compiled in the following order: title page; abstract; keywords; main text introduction, materials and methods, results, discussion; acknowledgments; declaration of interest statement; references; appendices (as appropriate); table(s) with caption(s) (on individual pages); figures; figure captions (as a list).

Word Limits

Please include a word count for your paper. A typical paper for this journal should be approximately 4000 words, this is a guideline and not a limit; this guideline does not include tables, references, figure captions.

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